ACCELERATED

THINKING AND PROBLEM SOLVING

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Abstract

The main objective of this investigation

According to Piaget, formal reasoning begins at 11+. The present study attempts to examine whether Piaget and Piaget type tasks could be tackled at 10+ or not. If not, could the children of 10+, be trained to tackle those tasks and thereby achieve what we can call acceleration of thought. This study was carried out on 33 children drawn at random from Grade VI of the Mother's School as well as the Mirambika School cited there. The latter is an experimental school where children are free to choose their activities according to their fancy and interest. There is little of regular teaching so nobody knows where the teacher or the pupil is at a particular moment. In other words, this school is full of activities. The problems were administered individually in two parts, first those which equalized experiences across the pupil population and secondly, the effect of this stimulation on the two Piagetian schemes of thought, namely, combination of coloured and colourless chemical bodies (real and in paper pencil form) and the oscillation of a pendulum. There were no time limits for solving these problems. The results were also compared with the past studies in terms of pattern of responses so far as status of thought without acceleration of thought was concerned. The results of this study indicated:

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(i) It is possible to discern a pattern of response. The coefficients of fluctation have remained under 10 per cent. It is within the acceptable limits.

(ii) This pattern of thought is hierarchically determined , using the Guttman scale.

(iii) It is possible to accelerate thought process under certain conditions but the abstract Piagetian schemes of thought are difficult to crack. The way out is to arrange several such tasks in the ascending order of difficulty.

(iv) It is very much possible, largely speaking, for children to help themselves in their day to day teaching learning process. The teacher should not always insist on right responses. Instead, he should help them to see the relevance of their responses in concrete situations. Time thus spent is not a wastage of time but the children are, in fact, revealing the evolving structure of their logical thought.

(v) It is hypothesized that it is equally possible to discern a pattern of thought in their wrong responses . It is also developmentally

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determined. If so, hump effect as hypothesized appears dominantly where path to concept development is not linear but children go forward, go backward and again go forward in their thinking. The occurance of errors (mistakes) on a particular process of thought across age/grade groups which suffers humps is, in fact, a matter of growth for it is temporary in nature.

The Child at the Centre of Education : A Developmental View

Background remarks

It is usually difficult to find a starting point for discussion in education. So it is desirable to talk off the tangent before coming to the point. Maria Montessori declared the present century as the century of the child. Even in the closing decade of the century, we have yet to improve his lot within the context of education. First, we have yet to develop a system of education which is based upon his growing natural abilities. Secondly, we are hammering at wrong places. Thirdly, we are increasingly making our educational system more pathological than it was, say, at the time of independence. Mass copying is a case in point. Fourthly, as if this were not sufficient, we are appointing senior persons as zero multipliers in the educational hierarchy. Lastly, the educational system is trying hard to deliver what it was supposed to deliver as initially imagined under the colonial rule. It should not be forgotten that only living nations have problems which each nation has to solve in its historical and socio-cultural context. Consider the following statements :

1. Ours is a big country and so are our problems. The problems facing us are gigantic. The resources

are highly limited for any improvement. It does not need repairs but is has to be built up continuously piece by piece to meet the drastic changes needed in our economy for attaining properity. For the, working lives of our children and youth have to be highly productive in all sorts of affairs. This widespread dissatisfaction is there in almost all the countries of the workd. In our clerical system of education, the schools from the view-point of functioning professionally, have "bottomed out". If some schools are succeeding somewhere, it is our hope that other schools can also succeed. It is only possible, if like every tub, each school rests almost on its own base (bottom). It does not mean that He school is alone in its own improvement. Or, it is like a solitary ship on an unchartered sea. Within the available resowces, it is the head of the institutions and his staff who finally determine how each paise is to be spent at their school with no holds barreds. Thus this sbhool is free to raise its own resources too. Lastly, the focus of improvement is on the whole school within its own commanity setting.

2. Competent teaching or professional service education is not at all a mere mixture of liberal education, subject matter, competency, pedagogy and vocational reflections. In the language of

Chemistry, it is a compound which does not share the properties of any its constitutents. This, in other words, means that the quality of education does not depend upon teachers or modules/textbooks alone. Or, does it depend upon the facilities available at a given school ? Again the answer is a big No ! Why ? It is the necessity rather than the facility which is the mother of invention. For example, differences in school facilities and resources marginally influence the inequality in school test score. There is no such direct input-output relationship, a point yet to be grasped by the research institutions. We have instead, to study the growing interactions among these variables and judge where to strike at the right moment (Coleman's report). John Holt, for example, was not far wrong when he said that there are no essential differences between dull and bright children because the formed forget before the examinations and, the latter, after it. He drew this conclusion while having a close look at the functioning of the most expensive schools in U.S.A. One should not be least surprised if research says that achievement at school can be enhanced if teachers entertain positive images about their students who are actually dull. Its vice-versa is also true (The pygamallion school).

3. Children are by nature very curious and eager to learn in the environment in which they live. Research on reading says that with them, any method of teaching works. The Piagetian research says that upto the

the age of ten, children continue to develop their own ideas regardless of the typology of schools. If adolescent pupils get into the habit of surmounting their self imposed restrictions on their thought processes, their individual minds become experimental during mid adolescence and early adulthood. A situation is fast developing in our country where children are rejecting not only their teachers but also their schools. If true, they are in a position to help themselves.

4. We are now talking of education for tomorrow, nay, for th 21st century. We are now trying hard to revamp everything in our educational system on a massive scale never witnessed before. Our schools will never improve if these remain the hands of defeated school masters, teacher educators and abondoned administrators. Neither passing of the buck not the art of flattery is the helpful measure in educational improvement. Schools have to take the character of workshops rather than wordshops so that we may succeed to lay bare the dynamism underlying our traditional mode of schooling. Schools will continue to instruct and educate and, thereby, function at an inferior level if we cease to reflect on what we are doing in the name of schooling. Not to do so is to court mediacrity. John I. Goodlad has aptly remarked :-

> Tomorrow's system of education will evolve if present arrangements are dynamic. But if we dig in our heels, become defensive of what now exists and engage in improvement only at the edges, the schools we have will atrophy. We will continue to educate our children but not necessarily in better ways. Surely, we can build from what we have, profiting from past experiences in search for something better. (1)

What about educational research ? Life in educational research is built upon talents, beliefs, perfomances, and habits of hard work. Better, if there is a leader too. Life in research is spent in exploration and weighing up of evidence for the development of objective knowledge. Errors do appear in judgement. Still our educational system lacks the research base and consequently loses its knowledge base increasingly. Result. It loses its vitality. The educational issues become consequently multi-dimensional. It is better, nay, preferable to drop the problem rather than to solve it for. We, unlike the British the lease empirical minded too when it comes to solve educational problems within the classrooms and outside too. It is not our case that our children are condemned to study the national curricula mechanically and unreflectively. Unless a miracle happens, such an educational race as it goes on today is going to take our nation down the hill. In this context, we can make the following observations about the status of educational research

in our country. These are :

(i) It is still crystallizing, so it lacks status. At the same time, it is there because the time for its crystallization is not far away.

(ii) Problems from the educational point of view or relevant to the needs of the country have yet to be formulated productively. The transfer effects of educational research findings to school systems and classroom use are to minimal to mention.

(iii) There is no distinct difference between the bonafide researchers; and the organisers as well as documentors of research. The latter usually rebuke the former for what they have not done.

(iv) There are few researchers in education in this country who have developed life long research programm We do not have our Spearmans, Vygotskys, Cattells, Vernons, Piaget and Piagetians around. So the educational Siberia is hardly cultivated continuously.

(v) Anything goes in research. Finding are not checked and cross-checked. At the same time, hardly any quality control is exercised as a matter of routine. In other words, findings go unchallenged and are usually accepted uncritically.

(vi) Teachers have little faith in training methods and use of research findings in classrooms. They rarely reflect over their practices.

(vii) Educational research is a field in which there are no stakes, no recognitions and no rewards ! There are workers who cry for conducting research. When helped, time is past.

Let this nation not become the victim of its own misjudged curricular and examination reforms. Let her look within for the real spings of action for filling in the black box missed by the behaviourrists. Its inner development is well illumined by the developmental psychology. Let us now see how the child goes about the business of constructing and reconstructing his own house of knowledge when Piaget happens to be the current star.

An Eye
to
The developmental view of learning

Education, as field of inquiry as well as practice, is very easy to verbalize about if not understood. Its inherent beauty is that the more it is understood, the less it is grasped. Even the various parameters of a simle term like 'child-hood' cannot be precisely specified. The so called principles of teaching, which have acquired natural status over the years, hardly

clarify anything psychological when it comes to the teaching-learning process in our day-to-day classrooms. The record of the contribution of educational psychology to the development of education over a period of 100 years or so is least flattering. The clerical system of education has done a lot of havoc both to our educational system and the natural development of children. Historically speaking, we missed the first industrial revolution. We now need not miss the second industrial revolution which has been knocking at our door-step for the last several years. Here, undoubtedly, our success depends upon the quality of mind developed at school. Our present-day teaching-learning process has to be simply reversed. It has to be based upon the processes of thought rather than its products; and that too in an open frame of reference. In other words, questions and answers have no longer to remain fixed for years as is the case today. The whole teaching-learning process has to be characterised by firmness, dynamism and discovery at the same time, resulting in the self-learner who is his own boss in disciplined imagination and thought as well as action. To that extent, he becomes an enlightened soul chartering his own course away from his own immaturity within the Gestaltean context of integration with other variables, say, intellectual, social, cultural and the real world of work.

The developmental view of learning, if taken seriously, is an alternative, rather anti-education system which has beeh talked about and advocated seriously, at least for the last twenty years or so. Its greatest exponent in this century was Jean Piaget of Switzerland. According to Piaget, child is essentially active. It is in his nature to learn. Nay, it is in his nature to go on learning and learning as well as refining his ideas continuously. He distinguished between development and learning but, at the same time, he, in his scheme, subordinated learning to development. Any normal child in his view is quite capable of forming sound scientific and mathematical concepts. Relevant logico-mathematical structures develop as naturally in him as, say, learning to walk. For the latter type of learning, he need not be aware of the laws of locomotion. Failure, of course, is there in abundance but is is immaterial. Why? The reason is that he is in a position which is going strong every moment, for he does succeed in rectifying his mistakes and thereby master his failures in the end. He thus becomes quite capable of using his own reasoning faculties for solving problems in his own environment. It is not all a case of nasty step towards self-education, the chief distinguishing characteristic of any first class educational system anywhere in the world. The continously reasoning individual is not at all a lonely figure or a cold-blooded creature. His view, on the other hand, is that maturation, experience (bothphysical and mathematical), social interactions and equilibrations (each one higher than the other) play their role in spontaneous development.

Let us, therefore, concentrate only on Piaget here.

Man and His Works

The work of Jean Piaget (1896-1980) is little known in this country. There are many reasons for this, the chief being that he wrote profusely only in French. Secondly, he was a very difficult author to understand because he took too much knowledge for granted on the part of his readers. Thirdly, having been trained as a zoologist, he developed imaginatively the biological theory of knowledge for which he developed his highly specialised vocabulary drawn from his own intensive investigations on mollusks: organisation, adaptation, reversibility self-regulation, cognizance, equilibration, etc. Over the sixty-year period, he wrote about 50 original books and over 1500 monographs, papers and articles. He observed his own children closely, played marbles with other, and, using a semi-scientific method, traced the origin of several diverse universal contents. He did not stop at this but, contrary to the tradition of John Locke, David Hume and I. Kant, attempted to provide experimental answers to the age-old philosophical questions about the nature of knowledge. It is of interest to point out here that these problems were raised right from the times of pre-Socratic philosophers which he attempted to solve in his own unique way. He, thereby, founded a new branch of knowledge called experimental epistemology. The philosophers of the day did not acknowledge him as a person of their tribe and, in retaliation, he did not regard himself as the one interested

in psychology, education and children. As controversy on controversy ensued, he contributed abundantly to the whole field of psychology: perception, reasoning, intelligence, dreams, moral development, space, time, play, thinking from early childhood to late adolescence, physics, mathematics, biology and logic. Some of the well-known books authored by him are : The Language and Thought of the Child, Child's Conception of the Physical World, The Origin of Intelligence in Children, Logic and Psychology, The Growth of Logical Thinking from Early Childhood to Adolescence, Genetic Epistemology, Insights and Illusions of Philosophy, The Origin of the Idea of Chance in Children, and The Grasp of the Consciousness. Nobody, even beyond a few kilometers away from Geneva in Switzerland, really understood the full import of his works. It is of interest to mention here that almost the whole credit of compiling the allied works on Piaget in several volumes goes to an Indian couple: Sohan Modgil and Celia Modgil currently based in England.

Some More Reflections

The ancestry of his work can be traced to early intelligence testing in Paris, France, by Simon and Binet. Accidentlly, he discovered there that pupils' errors on intelligence test items provided substantial clues to understanding the nature of intellectual development. In his entire work, he did not care to determine

the reliability and validity of his experimental tasks used for studying intellectual operations. Instead, he designed his own intellectual operations. In his work, he raised the status of an ordinary child to that of an universal child. As already hinted at, his technique of collecting data was too slack and shoddy. Equally true was his method of recording and presenting data for which he hardly touched any statistics far beyond frequency, mean and percentage. In his work, he did not make use of high speed computers which invariably is the practice today in carrying our scientific research. Still, he succeeded to relate the findings of his diverse studies to the origin of knowledge via the pupil's mind, for he took the growth of epistemology seriously. In sum, he provided insights into the varied ways the universal child goes about the business of developing his own incomplete house of knowledge. He was careful enough not to take any definite position on the nature-nurture controversy. Without meddling with the word 'creativity', he explained how the human mind goes on creating novelties, each more exciting than the other, over the years. He also believed that a teacher cannot give an idea to his students and, thus, distinguish between false knowledge and true knowledge. It is perhaps in this context that John Holt in his book 'How Children Fail' talked about the differences between dull children and bright children studying in the highly expensive schools of America. According to him, dull children forget before the examination and bright children after the examination. In the Piagetian context, on the

other hand, teaching means creating situations in which the underlying structures or concepts are pupil-invented through exploration. Unlike L.S. Vygotsky and J.S. Bruner, Piaget did not believe in the acceleration of mental development. He, therefore, stressed education for understanding, problem-solving and finding. He appeared to be silent on punishment, reward and motivation. Selecting cognition as the fundamental variable for intensive scratching, he showed that action is the basis of all knowledge which is replaced continuously by a series of continual reflection inside the head of the growing child. Learning by doing alone is inadequate if it is bereft of learnin by thinking or reflecting. The everlasting nature of his work backed up by hard evidence can thus be appreciated. To illustrate, a child is not simply a scaled down adult becuase both see the same thing in a different way. Childhood is, therefore, not a necessary evil which is to be tolerated at any cost. Nay, it is an inseparable part of the whole development as understood logically by the adults.

Stages and Success

Intelligence, according to Piaget, develops in four stages. These are : sensory motor (0-2 years); pre-logical (2-7 years); concrete (7-11 years); and formal (11-15 years). Before his death, he hinted at the possibility of a fifth stage which extends from 15-20 years and takes into account aptitude variations as well as highly varied individual career commitments. This stage is now seen against the less prominent, general intellectual development

of the preceding stages. Returning to the first stage, it is of little educational significance but, at the same time, the foundation of practical knowledge or pre-verbal learning is laid here. Minus language, his mind becomes truly inventive during this stage. Thinking during the second stage, resting, of course, on the first stage, is transductive. In other words, it is from particular without underlying any generality. Thinking here is self-centred because a child makes judgement the way he sees the situation. At the third stage, his thinking is dominated by the reality or the content of the situation. At the fourth stage, the earlier situation is simply reversed and the adolescent pupil lives in the world of possibilities and ideas. He is now in a position to set up all sorts of hypotheses and test each of them experimentally through control experiments. He is, thus, in a position to pick up the various elements of scientific methods. Piaget does not stop here, for he succeeds to hook the various scientific patterns of thought to the origin of knowledge as seen historically. In this widest theoretical frame of reference, he also enunciated conditions under which thought moves from the lower stage to the higher stage of development. It is interesting to note that in the early stage of his work, he literally ran away from psycho-analysis. But towards the fag end of his life, he did explain how conscious, pre-concious and unconscious hang together.

Understanding of the World

There is distinct difference between child thought and adult thought. Let us now mention briefly how the child begins to look at the world within the framework of nine universal contents which possess universal interest and appeal. Due to the paucity of space, let us confine the scope of discussion only to the first stage and the fourth stage of intellectual development as propounded by Piaget is :

1. Action
2. Object
3. Space
4. Time
5. Causality
6. Play
7. Imitation
8. Language (2)

S. No.	Contents	Sensory Motor Stage	Formal Stage
1.	Action	Representational thought emerges from reflexive physical actions.	It operates in a wider context and is a function of the Piagetian logic, say, combinational, propositional and INRC group. It is a kind of idealized situation.

S. No.	Contents	Sensory Motor Stage	Formal Stage
2.	Objects	Initially, there is no concept of permanent objects. It develops during this stage. Objects no longer disappear even if these are out of mind too.	Conservation is superseded. Instead thought becomes hypothetic-deductive in nature. It is a function of the Piagetian logic, namely, combinational and propositional.
3.	Space	There is no concept of space in the beginning. Immediate space is conceptualized at the end of this stage.	It now appears as relative space.
4.	Time	The concept of time as such does not exist at the beginning of this stage. However, there is conceptualization about short intervals or sequence of durations: tea time, meal time and play time.	It now appears as relative time.
5.	Causality	Initially, there is no concept of cause and effect. However, towards the end of this stage, there is conceptualization of simple cause-effect relationship.	Idea now is tested through controlled experimentation, for example, exclusion of variables.

S. No.	Contents	Sensory Motor Stage	Formal Stage
6.	Play	Symbolic play appears at the end of this stage from the repetition of reflixive activities.	It gives way to reflective abstraction and hypothetical thought.
7.	Imitation	First deferred imitation appears from reflexive activities	It gives way to reflective abstraction and hypothetical thought.
8.	Self	There is no concept of Self as such in the beginning as it stands merged with the environment. However, there develops gradual consciousness of differentiation of self and others.	Reduced ego-centrism gets further reduced. Instead, ideal self appears.
9.	Language	First language appears when there was none in the beginning.	Practical language gives way to abstract language.

A few comments here are quite relevant for elucidation purposes. First, the child uses the various parts of his body in learning: hand, arm, feet, ear, head, tongue, and nay, even the skin. He tries to draw full benefit from various motor reactions in his perceptual field. He tries to lay his hands

on anything which is within his reach. These are in a way his technologies or means of acting on things and objects. To illustrate, he has not to be taught how to put his fingers into the hole of a towel or a handkerchief. Why? He does the entire operation unaided. Problems however, arise when he tries his hand, say, on bottles, locks and power plugs. At this stage, care as well as caution by the adult is a must. At the same time, he still retains the option and is in a position to communicate with others. Thus elucidated briefly is the Piagetian concept of action. From this initial learning obtained on his own, the child is able to expand his efforts hot only within a given set of situations but across the other on learning and re-learning ceaselessly. In fact, his progress is endless in all directions but stands little documented in literature. The point not to be missed at all is that the idea in the head of the individual child is fully free to go anywhere and develop itself in any way it deems fit depending upon the passionate pursuit of the individual concerned. If it happens: he no longer than develops problem-solving strategies haphazardly and inefficiently. Here, the Gestaltean advice is: Teach organically. Let us now quote some research findings on the formal stage in the form of key statements.

Some Key Statements

It is difficult to review all researches in this area. Some reviews are already available. It is not easy to interconnect the findings firmly because of

varying objectives, tasks, samples, tools and tests and the modes of interpretations. All these findings when consolidated boil down to the following conclusions :

(a) The human mind is highly dynamic. It acts on its own and thus possesses quite a bit of spontaneous thought. It is a readily available reservoir of continually developing thought which, on close reflection and controlled experimentation, can be used easily for the development of various concepts underlying several school subjects.

(b) The concrete operational stage is quite dominant among normal adolescent pupils. Whereas adolescent pupils are in a position to set up hypotheses, they are not in a position to test them. In other words, their minds have not yet become experimental. Further, they are also not in a position to exhaust all the possibilities or combinations and permutations. At best, they can test one variable at a time in most of the cases.

(c) They stick to their thought firmly. They also enthusiastically prefer to test their ideas in the first instance. When compelled to think, their erratic individual processes of thought appear to suffer hump(s), before individual concepts finally settle down in their individual heads.

(d) There appears significant relationships between the scores on formal thought and the several outside variables, namely, mental age, grade and age, some personality traits, socio-economic status and the type of school management, sex differences favouring boys in problem-solving exist but these need to be studied in relation to race, country, religion, rural/urban divide and varied conditions of schooling. Here our limited observations are:

(i) There are no sex differences in problem-solving if boys and girls are treated equally at home.

(ii) There are sex differences in problem-solving favouring boys, if boys and girls belong to backward areas of the region or districts.

(iii) There are no sex differences in problem-solving if both boys and girls belong to the bottom group. In the top group, they try hard to succeed and equalize their performance. However, there is a general tendency to think maximally among all adolescent pupils on the Piaget-type tasks. These tasks definitely fire their imagination for quite a long time.

(e) It needs to be stressed that different school subjects demand varying amounts of formal thought. Mathematics and physics demand the maximum. Secondly, the role of past experience and hints

and clues is little understood in problem-solving. Hints and clues only favour thouse who are at the transitional stage of mental development, that is, between the concrete stage and the formal stage. Thirdly, whereas a problem is solved in stages, it is at the same time very difficult to specify sharply the parameters of these stages. The concept of stage simply serves a practical end from the teachers' point of view.

(f) The very language of Piaget as well as of the Piaget-type tests is deceptive. It is, therefore, essential to establish equivalence among the various tasks empirically. Otherwise, it is difficult to reconcile contradictions in various findings. For example, a problem supposed to be formal may turn out to be a concrete one and vice versa. Secondly, there is seen a sufficient time lag between the experimental solution and the formal solution.

(g) Like Piaget, teachers should lisken more and more to the inaccurate answers of their pupils. On the basis of knowledge thus gained, they would be in a position to improve their strategies and tactics of teaching. Secondly, it takes time for schemes of thought to develop. In fact, their development from year to year is too gradual, laborious and slow. However, content and instructional intentions

are some of the factors which definitely influence learning. Thirdly, self-learning and pupil-to-pupil interaction in class may be encouraged and search be made for promising results, if any. Pupils may thus open up in their own learnings unaided. Lastly, pupils use words metamorphically. Our lack of knowledge about where to hammer at rather than go on hammering all the time makes access to the child's mind difficult.

(h) Psychometric and developmental studies on intelligence have yet to converge. There are a number of cobwebs yet to be removed from the theoretical point of view. It is worthwhile to explore whether there is a distinct possibility of a fifth stage to appear on the scene. Its existence had been hypothesized by Piaget towards the end of his life. It would then take care of aptitude variations and career commitments on which Piaget had little to say in his writings (3).

The role of the teacher as an agent on intervention says but in an entirely different context, the context being the framework for facilitating learning as propounded by the National Education Policy of 1986 where the teacher no longer acts as if working at an academic pump. In other words, when the developmental view to learning is kept at the focus, children not only enjoy varied learning but also work to their capacities fully. Unintendly, the present day teaching process also gets decentralised for new stimuli rather than responses also get mastered over the years.

This is, interestingly enough, also advocated by the National Education Policy.

Impact and Evaluation

It is, thus, strange that the Piagetian system of thought had little to say on education. True, it does not generate variable as well as testable hypotheses via psychometry. But his work is supported in principle far beyond the borders of Switzerland including India. Any piece of psychological research conducted anywhere in the world remains out of tune without reference to his work. He safely pushes aside the basic positions of stalwarts like Sigmund Freud, J.B. Watson, B.F. Skinner, Max Wertheimer, L.S. Vygotsky, J.S. Bruner and Kurt Lewin. He thus occupies the topmost position in the field of developmental psychology. It is, therefore, least surprising that his work has evoked simultaneously widespread acclaim and ridicule. Taking an overall view, one would have heard little of the science curriculum improvement project in the U.S.A., and the Nuffield Science projects for the youngsters as well as 5/13 science project in the UK. In Australia, K.F. Collis and J.B. Biggs would have been in a pretty difficult position while developing a SOLO Taxonomy (structure of Students Learning outcomes) nearly at par with Bloom's Taxonomy. At home, the writer would not have worked on the factorial structure of adolescent thought within the developmental context for years; run an individually accelerated science teacher education project; developed a Science Teacher Behaviour Inventory; and

hinted at the existence of Hump effect during problem-solving when substantial departures are observed within his general development of logico-mathematical structures. And the Modgil couple would have been hammering at something else in England. It is easier to see the relevance of several educational ideas and projects currently at work in our country. Examples of such projects are : The Hoshangabad Science Teaching Project in Madhya Pradesh; The Mirambika Experiment at the Mother's International School, New Delhi, and the regeneration of the Pushkar Valley Lakes system in Ajmer in which education, development and employment are inter-hooked firmly.

If to study knowledge is to study man, our knowledge about the human mind then stands highly enriched abundantly because of the Genevan works characterized by speculation as well as slipshod experimentation. He founded experimental epistemology in the true tradition of scholarship trailed earlier by the greatest philosophers of all times, namely, Socrates, Plato and Aristotle about 2500 years ago.

Final Remarks

It is, therefore, in the fitness of things to read about such a great thinker who lived passionately for his subject. In his own time, he virtually defined the whole field of cognitive development. Why ? The Answer is that he was a great polymath who did not at all hesitate asking big questions and that too in the right order, considered difinitely out of reach by psychology in his times.

He provided experimental answers to the age-old philosophical questions. It is worth reiterating that failure in science is not a rare event. At the frontier of knowledge, one has to suffer being a joker at times, when intially speaking, it comes even to suggesting, any relationships between experimental epistemology and the entire range of human sciences. Unfortunately, it is everybody's impression that it is very difficult to read the Piagetian works. If read, it is very difficult to understand them; if understood, it is very difficult to write about them; if written about, there are misinterpretations galore. So to read him is to misread him. To understand him is to misunderstand him. To interpret him is to misinterpret him. And to judge him is to misjudge him. In sum, not to reflect on his works is to court mediocrity, for he is trying to say something quite different and perhaps valuable too.

He focussed clearly in his works on the life of the mind. He explained clearly why children given responses to his questions as they do. He viewed learning as a fascinating struggle to be enjoyed and how it leads to restructuring of knowledge in an open frame of reference. And how, it is within the realm of possibility for practising school teachers, to enrich reconstruct school curricula imaginatively on the cheap; and that too, at the input level. Children are reasonable, capable and clever problem-solver too. When grown up, they shape scientific thought marvelously in their own unique ways.

Since Piaget is now dead, he can be evaluated quite objectively. Each critic, whether he agrees with him or not, acknowledges the greatness of his works. The whole benefits are ours if he is unseated from his present position of prime importance by somebody's superior challenge. But it is in the nature of the Piagetian journey which lets any one work ahead productively in thousand different ways in one's own area of professional freedom. Until such an historical hammer falls on Piaget, we should continue reading and reflecting on his works. Nay, his works may be replicated and tested at their weakest points experimentally. It is precisely this Henri Bergson, in Creative Evaluation, talked of when he said : To exist is to change, to change is to mature, to mature is to go on creating oneself endlessly.

Lastly, when the child is placed at the centre of education firmly, it is advised that everything be not pre-determined for him. The scales of teaching, learning and testing of environmental experiences including experimentation need to be tilted firmly in his favour. In other words, children need to be given a lot of say in their own development and education. Otherwise, our efforts are going to be counter-productive in every possible way. Raising percentage of achievement, though desirable, is not going to solve our educational problems. We have accomplished our job if we help children to help themselves.

Let us remember what the Chinese philosopher Lao-Tse said :

> If I don't drive among people they look out for themselves. If I don't preach at people they become themselves. A leader is best if people hardly know that he exists. A leader is not so good if people obey him and cheer him. A leader is worst of all when they scorn him. About a good leader who says little, when his work is done and his goal achieve, they will all say "we did it ourselves". (4)

And this is what Confucius, Buddha, L.S. Vygotsky, Gandhi, Tagore and Vinoba, a few out of the many, have been hammering at for years in their working lives.

PREFACE

SINCE MAN has always been a ceaseless enquirer into scientific, technical and social studies, his concern for the development of children, teachers and teacher-educators is growing in importance. Educational ideas, like scientific probings, did not develop in a vacuum, and they have their principles 'rooted in the wisdom of the ages,' traced back to the ancient Greek thinkers like Socrates and Plato. Since then the ideas of many great thinkers, representing different disciplines, have been woven into the fabric of current educational philosophy and practice. And Jean Piaget drew heavily from this great philosophical reservoir. While doing so, he appears to have paid back his ancestral debt abundantly in his own lifetime. For it is impossible to imagine today a cognitive study without any reference to his work. Whether one agrees or not, a dip in the 'Ganges' of Piaget does affect one's outlook on eductional problems. Why ? Because he presents a series of challenging syntheses as obtained in the rationalist tradition of Plato, mental categories of Kant, the Bergsonian notion of perpectual change, the findings of Gestalt psychologists like Max Wertheimer, the use of logic for interpretation of thinking (classes, relations, grouping, reversibility and equilibrium), and in the

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revelatory statements made by personalities like Calvin, Rousseau, Pestalozzi, Claparede, Binswanger, Bleuler, Rorschach, Meili, Jung and Sechehaye.

Philosophical problems present themselves to the philosophers, perhaps in the true tradition of their beloved field of enquiry, in unsolvable form. Piaget, while still remaining a firm speculator, succeeded in psychologically tackling an age-old epistemological problem as enunciated by Plato: "How and when can man be sure that this knowledge is true knowledge, when time and again he finds that what he took to be knowledge has proved to be knowledge has proved to be error". In this, he not only substituted the fairly well-established scientific procedures with his own Methode Clinique, but also constructed his own symbolic logic for interpreting intellectual operations as they develop from the very earlier childhook to late adolescnce. He thus showed how a child, nay, a 'universal child',goes about the business of constructing his own house of knowledge. Continuously challenged by this problem over a period of forty years, he came up with this grand hypothesis:

> Development is continuous not only within the individual but throughout all

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evolutionary levels. From the biological to the social to the intellectual levels, the unity of nature is preserved. The functioning of the loveliest mollusk is based upon the same fundamental processes as that of an Einstein.

The Nature of the Problem

Thinking is a 'ghost'-like activity, for it has to be inferred rather than observed. In literature, it has been referred to as "abstracting, analysing, comparing, deducing, defining, discriminating, estimating, generalizing, guessing, imagining, judging, knowing, opining, reasoning, recalling, recognizing, reflecting, remembering, searching for conclusions and understanding". While going ahead, one has to cross the territory of 'concept formation,' which again jturns out to be a vast area of investigation in its own right, having strong links, but not identical with, such complex psychological processes as thinking, learning, problem-solving, language acquisition and symbolic representation. If this journey is further continued, one enters the complex areas of problem-solving, creativity, critical thinking and originality, where one is usually caught in a quicksand pit of definitional difficulties. One is very lucky, if for every milligram of information, he spends a quintal of effort. And at this point the distinction between original sense and original non-sense disappears.

Not long ago, the nuclear scientist Oppenheimer aptly remarked: " It is the business of science to go wrong". Difficulties for the cognitive psychologists, therefore, go on multiplying, and for achieving success, problems have to be posed more and more productively in the phraseology of Gestalt psychology with a view to investigating the complex processes of thinking, which may ultimately lead to the development of understanding, generalization, discrimination, concept development and attainment. The problems, however, do not end here, because the researchers and the practitioners do not invariably ask the same question. These split-questions, and possibly the consequent split answers, are bound to appear in the business of any science, educational psychology being no exception. The workable solution under these circumstances lies in considering the two isolation as is frequently done in meeting the anolalies in science. The basic problem here is to relate the most mental development of children whose answer goes a long way in providing the psychological structure to any one of the school subjects. Thanks to the recent efforts of Ausubel, Bartlett, Beard, Bruner, Flavell, Gagne, Guilford, Hans Furth, Hearnshaw, Humphrey, Inhelder, Lovell, Lunzer, Peel, Kraplus, Piaget, Schwab, Skinner, Suchman, Vernon, and Wallace, the problem-terriroty in this decade has been sufficiently explored

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and consequently, the problems in piece -- like the discovery of fundamental particles in atomic physics - lie more in the zoo rather than in the jungle.

This was hardly the case over twentyfive years ago. The emerging literature of thinking clearly tells us that children learn spontaneously, and they acquire schemes of thought regardless of school influences. They learn from each other, and learn equally well in formal situations. At the same time, they also possess first hand knowledge about men, and their affairs in the immediate environment. This, however, does not amount to saying that the sun rises in the east or sets in the west. It only means that the child's thinking is not at all a chance or random behaviour. It is sensible, intelligible and predictable against the available theoretical psychological constructs.

Problems Posed in the Field

In this perspective, the field as a whole poses the following problems which overlap each other to varying extent:

(i) Specifically speaking, what are those conditions under which learning takes place maximally? What exactly is the role of hints and clues either in supporting thinking or in the formation of concepts? To what extent can concepts be downgraded?

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ii) At what age is formal reasoning manifested among different categores of pupils? How is formal reasoning different from concrete reasoning? What are the conditions that determine transition between the two stages?

iii) How is thinking generalized in each of the two grades? Does it develop in stages? Is it possible to accelerate stages? What is the role of planned experiences in concept development and problem-solving? Is creative thinking also influenced as well ?

iv) Does 'instruction precede development' (L.S. Vygotsky)? Is learning to take place mechanically or from page to page within the textbook? Or, is it possible to save children from subsequent teaching, once the initial learning has been fully acquired ?Quoting J.S. Bruner: "" Is it possible to get a maximum of travel of what we have learnt?' If so, what kinds of thinking processes does training generate under different conditions? Are they the same as the preceding ones or are they different ? Are they of temporary or of permanent character ?

(v) What errors do the children exhibit at various age levels? Are they, psychologically speaking,

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interpretable? Is it possible to develop a museum of these errors ? Is it possible to demolish this museum through intervention ? What is the role of maturity in this connection?

(vi) Is learning possible in the absence of schemes of thought in relation to academic subjects taught at school? Do these schemes of thought have any psychological existence or relevance?

(vii) Why do the children fail to verbalize their concepts or methods or procedures, especially when they have, in fact, acquired them ?

(viii) Do children regress in thought while solving problems? Lastly,

(ix) How do the children coordinate information? What are the underlying mechanisms? Have they strong links with symbolic logic? Are they of any psychological significance as well?

The present report is in two parts. The first part contains the following chapters which are:

(1) Nature of thinking.
(2) Problem solving.
(3) The Piagetian concept of knowledge.

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(4) Studies on problem solving in science.

(5) Accelerated learning.

(6) The present study.

(7) Teaching for combinatorial grouping.

(8) Teaching for exclusion of variables.

(9) The final version of Hump Effect in problem solving.

(10) Focus on education: a developmental view.

The above mentioned chapters are not complete in themselves. So the second part of the study contains chapters which strengthen the various chapters of the first part. These are:

Further theoritical considerations.

(1) Delving deep into science education.

(2) The puzzling ways of science.

(3) Developmental epistemology and fundamental problems.in the theory of knowledge.

(4) Piaget and education.

(5) Improving formal reasoning: A comparison of variables training and strategy training.

(6) Relationship between inellectual development and scientific concepts.

(7) Defining the process of science.

(8) Process and product in science teaching.

(9) Teaching science through discovery.

(10) Improving classroom instruction in science.

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The chapter "Puzzling ways of science" strengthens the Piagetian concept of knowledge on historico-critical dimension.

The "Developmental epistemology and fundamental problems in the theory of knowledge" strengthens the Piagetian concept of knowledge in a highly abstract manner. If at the moment is a critical appreciation of the Piagetian framework.

The chapter "Piaget and education" supplements pinpointedly some of the ideas contained in the last chapter of part-I namely "Focus on Education - A developmental point of view".

Ours was a short term project. It could not investigate the relationship between intellectual development and scientific concepts. Hence a paper "Relationship between intellectual development and scientific concepts" was included.

There is confusion between processes of science and products of science teaching. We have referred to these terms in the first part of the study. These terms are clearly described in chapters 8 and 9.

If meanings of these terms is understood, naturally, it is not difficult to understand the context in which learning by discovery can be handled in our classrooms.

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We could not accelerate the thinking process of 10 year old children on the simple pendulum problem. This experiment needs to be repeated with added objectivity. For this the paper "Improving formal reasoning - A comparison of various training and strategy training" by Marcia C. Linn and Kevin Delucchi is highly relevant. This experiment then can be planned, designed and executed more efficiently.

Evaluation is a very important term in judging the effectiveness of teaching. It is possible to improve classroom instruction through appropriate feedbacks. Chapter 10 achieves this objective.

Lastly, the Piagetian Questionnaire was developed for the benefit of future workers who can pick up tasks from the questionnaire for investigating logical thinking over a wide age range.

An exhaustive bibliography and glossary are so appended to part-I of the study. Suggestions for the improvent of this report are solicited.

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PART - I

The Nature

Of

Thinking

Delimitation of scope

Dimensions of Thinking

Concluding statement

Human mind, unlike the idotic computer which depends upon commands to be issued before it gets into action is equally full of limitless possibilities. We may not increase its capacities but hopefully we can unlock them, using appropriate educative experiences suitably matched to its level of intellectual development. The most important task of the science of education today is to draw up that instructional manual which tells us where to hammer rather than go on hammering mechanically and infinitum.

N. Vaidya
in
Jean Piaget with love and
understanding

Experience is a dear teacher, and only fools will learn from no other.

Benjanium Franklin
in
Poor Richards Almanc

Genius is rare because the means of becoming have not been made commonly available. (1)

Luis Alberto Machado

The Nature of Thinking
and
Problem Solving

Delimitation of Scope :

Human thinking is as vast and deep as sea. It has given us our present day scientific and literary culture : an aspect whose roots can be traced to the distant past, not a difficult task. But more difficult, intriguing and mysterious has been the very investigation of the phenomenon of human thinking for in its entire history, it is only in this century that the experimental science behan to interest itself in thought. David Rapport aptly remarks :

> The knowledge that thinking has conquered for humanity is vast, yet our knowledge of thinking is scant. It might seem that thinking eludes its own eye. But this may be an illusion, and the eye is perhaps not searching but only staring... Whatever its nature, thinking comes to the point of invention, discovery and creating only in some human things, it serves most of us merely to the point of at least understanding what the few have created. And yet the dream stuff out of which world-changing thought is made is present in all of us, in the sentence - fragments of the brain injured, in the delusions of the schizophernic and in the babbling of the child. This is its enigma (2).

He further reminds the readers of his childhood experiences at school when he either hesitated or failed to anticipate steps done for him by the teacher. Why ? He further adds :

> Disappointed and puzzled, I ask myself why I cannot foretell the step, when it is so self-evident after I see it done. I must have asked this question countless times before when impressed and hurt in pride by adult omniscience. But I have asked it continuously ever since: the attendant shame and bitterness may have faded, the curiousity and puzzlement have not.

The above statement adds to the difficulties of any reviewer while surveying theoretical stand points as well as specific researches on human thinking even with special reference to science education at the school level. Prima facie, there are four ways to delimit the range and scope of this contemplated survey: by historical survey; by subject matter, that is, by drawing scientific concepts from different branches of scientific knowledge; by purpose; and lastly, method with little reference to scientific attitudes and personality variables. At its best, these four categories are not independent of each other; and hence can be regarded as dependent dimensions which need to be fused with a view to see the entire spectrum of human thought through a single crystal ball, quite an impossible task ! By such narrowing down, it may become feasible to understand the spectrum of thinking from the educational point of view. It is still

stressed that studies relating to animal thinking, human thinking (autistic, associative, creative, critical and integrative); language and thinking; concept formation (concept attainment as well as predictive relationships, abstraction, generalisation, memory, imagination, attention, believing, judging); comparative effectiveness of teaching methods or techniques; transfer of training or learning tasks and lastly, learning theories will continue to be valuable. The reason for this is simple enough because the present investigation deals with cognitive processes of thought from the developmental point of view within the problem solving context. It should not be lost sight of that not only the research literature in this area is vast but also the major aim of cognitive studies is to describe the growth of concepts by detailing the underlying processes of thought by which these concepts are acquired and applied to use. Lastly, on examining the relevant literature on thinking, one finds that it has been investigated from several viewpoints.

(1) S-R theories
(2) Conditions of learning by Robert Gagne
(3) Phenomenology
(4) Gestalt theory
(5) Factor analysis
(6) The Geneva School
(7) Accelerated learning
(8) Factor analytic view
(9) Ecological psychology
(10) Information processing

If the philosophical, psychological and epistemological rootings are ignored, the present study makes use of three basic motions underlying these two psychologies for investigating thinking. These three notions are : insight,

productive thought and the gradual mastery of thought. Once this view is kept in focus, it is then not difficult to attempt acceleration of thought and that too of lasting value. (3)

Man thinks and thinks on thinking, nay, he reflects again and again on what he thought, decided and did. The entire course of action, hypothesized and real, is brought under the close scrutiny of what we call "thinking". He is, then, set apart from animals who do think but to a limited extent. Kohler showed that even chimpanzees are capable of demonstrating insightful behaviour. Thinking as such does not fall from heavens. It as such does not arise all of a sudden. It, on the other hand, develops gradually right from the very moment man comes into the world (4). The philosophers, in fact, have investigated thinking right from the times of Socrates, Plato and Aristotle onwards. The logicians, in fact, went a step ahead when they developed their own laws of thought for judging flows in products of thought. Examples of the latter are : law of identity, law of contradiction and low of excluded middle. At the turn of this century, psychologists placed a lot of faith in faculty psychology which regarded mind as made up of several individual abilities, each amendable to training in isolation. Initial success with it resulted in the theory of formal discipline, a major educational achievement which was exploded, later on. The pure psychologists both European and American, investigated thinking from their highly varied stand points with little attention paid to problems of classroom instruction. The educational psychologists, on the other

hand, examined thinking through the medium of problem solving but the actual process of thinking eluded their attention. For example, C.E. Spearman regarded the following theee principles of significance in thinking, namely, "apprehension of experience, education of relations and education of correlates" which are quite sufficient for explaining the entire spectrum of intellectual behaviour (4). On surveying the relevant literature, it appears that the following aspects of thinking have received attention over the years. These are : Abstracting, Analysing, comparing, deducting, defining, estimating, generalizing and understanding. It has also been applied to a determined course of ideas, feelings, formulation of propositions for. Humphry thinking is equated to problem solving. Gestaltists have emphasised upon the perceptual and problem solving aspects (5). Barhelt views it as a high level skill in which symbols, shapes, colours and words assume importance (6).

Peel has distinguished among four kinds of thinking: Thematic, Explanatory, Productive and Integrative (7).

Rusell suggested his own scheme starting with stimulus patterns (internal/external) though materials of Thinking (Perceptions, images, memories and concepts). He concluded that thinking is amenable to learning (8).

In "The Encyclopaedia of Educational Research", Wilhelm , while surveying the area of thinking, has pothesized that whereas the materials of thinking numerous, the number of processes appear to be

and here, 'research data being incomplete and
"From the above it is clear that is difficult
to define thinking and even when its
explanatory concepts themselves become suspect and
consequently require further explanations."
The whole position on thinking is well summarized in the words of Hearnshaw when he says that thinking need no longer remain a ghost like activity. It is invariably as well as inseparably linked with the personality variables of the thinker himself.

Thinking can be described as inferences made from possibilities, evidence and goals that are discovered through searching. This is a firm frame-work as the starting point for thinking. It is difficult to image "SEARCH" in the absence of goals, possibilities and evidence including use of it. In a way, these are mutually related to each other. While examining, say, a belief, one can see the relevance of certain types of thinking such as learning from observation, setting up possibilities and testing them (scientific thinking), detecting the sources of trouble (diagnosis), discovery of general rules and principles (reflection by philosophers and linguists) and prediction of results. In some cases, use of insight is also helpful. Lastly, we also reflect our social relationships and, in the process, seek satisfaction, reward and success, a case of behavioural learning.

In this search inference framework, thinking is obstructed because of certain reasons which are :

(1) When one think too much
(2) When search made fails to see the relevant/significant fact/concept/detact
(3) When we infer on evidence which is shary and one is chealed by preference of a particular possibility.

The study of thinking is important because the spin off advantages lie in several directions. For example, it is the main job of the school to enhance the cognitive growth of the pupils under its charge. Now it is being said increasingly by many people of all shades that it is the main job of the school to enhance the cognitive growth of the pupils under its charge. It, in other words, means it is their job to teach pupils/children how to think. Nay, they say that children, adolescents and adults lack thinking skills when it comes to solving problems which are personal, social, scientific and technical etc. They lack abilities to write and communicate reflectively and creatively too. As the study of thinking is as old as man himself, philosophers, psychologists, educators, teachers, economists, decision makers (scientists and computer scientists as well) approach the problem of thinking in highly diverse ways.

It will be irrelevant if no reference is made to the works of John Dewey who dominated the philosophical and educational scene during the first half of this century. He equated it with problem solving and thus avoided the pitfalls of both traditional empiricism and a prior rationalism. He clearly brought out the "Ryle's ghost" from the machine and subjected it to empirical scrutiny tied to purpose.

Reflection on it no longer remained distant. Why ? He regarded thinking as a function of an obstacle in the way of goal directed activity. He, thus, stripped thinking of its philosophical aspects as outlined by Descartes, John Locke and J. S. Mill. Nay, he went further when he gave it a form of physical process of natural sciences manifesting in man while coping with his environment. It is an interesting and exciting enterprise when one is able to go ahead. On the basis of incomplete information for working at the edge and corner of thought is matter of achievement, pride and fulfillment. Starting from the first fundamentals, Jonathan Baron puts the entire discussion on thinking within the Search-inference framework by saying somewhat as follows.

The dimensions
of
Thinking

The study of thinking has taken many forms in the field of psychology such as behaviourism Gestalt psychology, developmental psychology, psychometric approach and information processing ( ). Let us now refer in brief to the dimensions of thinking which can reorient aid as well as restructure the conceptualization and implementation of schooling through curriculum design, instructional pedagogy and assessment techniques. These dimensions are :

1) Metacognition
2) Critical and creative thinking
3) Thinking processes
4) Core thinking skills.

DIMENSIONS OF THINKING

The dimensions of thinking can restructure the conceptualization and implementation of schooling by providing a new framework for curriculum design, assessment techniques and instructional pedagogy. The dimensions are briefly discussed below :

Dimension	Explanation
(i) Metacognition	This refers to an awareness of one's own cognitive processes and thereby developing "self regulated learning skills". Student ought to become more responsible i.e. develop "Skill with will".
(ii) Critical and creative thinking	Critical thinking is related to looking for evidence, being farminded and accurate, creativity is related to originality of ideas.
(iii) Thinking Processes	These lead to acquisition of new information. The processes involved in the process of acquisition are concept formation, Principal formation and comprehension.

Dimension	Explanation
(iv) Core Thinking Skills	These aid in focusing, information gathering, remembering, organising, analysing, generating, integrating and evaluating.(9).

Concluding statement :

We respect life. So we respect man and his thought. Both have given us our present day cultural, social, scientific and technical heritage. Nay, they are continuously transforming the world in which we live. But what about the child (not a little man) and his thought (not childish thought). For him, critical and creative thinking, core skills and capacities to process information and solve problems will not fall from the heaven.

It is true that thinking is not valued in our schools because our society is becoming fast a "marks oriented society". If so, our students won't become logical, clear, accurate and fair minded. To quote Piaget :

> The principal goal of education is to create men who are capable of doing new things not simply repeating what other generations have done - men who are creative, inventive and discoverers. The second goal of education is to form minds which can be critical can verify, and accept everything they are offered (10).

Problem Solving

Introduction

Definitions of Problem Solving

Stages in Problem Solving

The illustration of Problem Solving
through the Scientific Study of a
Candle : a student-teacher Partnership

Listing some Problems for stimulating thought

Concluding Statement

He who never made a mistake, never made a discovery.

(Sanuel Smiles)

Turning the accomplishment of many
years , Into an hour-glass: for the which
supply, Admit me Chorus to this history;
who, prologue like, your humble patience pray,
Gently to hear, kindly to judge, our play.

(Henry V, Act I)

Introduction :

This is the cry of the hour. As a method of teaching, it enjoys the highest prestige as compared with other methods of teaching, say in science and mathematics. It is quite another thing that due to certain physical limitations, teachers find it difficult to apply it in the classroom and the laboratory. Still, it remains the most distinguishing aim and the ideal strife in any educational system in the world for its immediate links with self education or self propelled learning after the formal education is over. There are, however, controversies over the age at which training in problem-solving should begin, the exact role of the teacher in this type of teaching-learning process for various categories of pupils at various age levels in different cultures (sex and socio-economic differences also not excluded), the pattern of curriculum organisation and the paraphernalia of curriculum materials required. If these controversies are considered and attempts made to improve the situation, it is very likely that it will necessitate changes all around, that is, within the school, in the educational set up and the examination as well as evaluation. Even the teacher training will not escape attention. To quote John Nisbet :

> ... ... It is not a matter of adding to the existing structure, but of radically changing the nature of that structure.
>
> Thus teaching thinking implies a profound change of attitude to education, knowledge, teaching and learning. Already I suggest, no curriculum can be regarded as acceptable unless it can be shown to made a contribution to the teaching of thinking (1).

It is of interest to add here that Gestalt psychology, according to Dr. Irwin Slesnick, visualises an active role for the learner in his learning process. Why ? He is not at all a passive entity. Max Wertheimer, the founder of Gestalt psychology, was extremely dissatisfied with the then existing approaches of traditional logic and association theory. He posed to himself the following question and attempted to answer it as well.

What occurs when, now and then, thinking really works productively ? What happens when, now and then, thinking forges ahead ? What is really going on in such a person ? These are not easy questions to answer when solution depends upon observing such processes as they actually go on in the mind.

What really takes place in such processes ? What happens if one really thinks, and thinks productively ? What may be the decisive features and steps ? How do they come about ? When the flash, the spark ?

He goes on to speculate about conditions, favourable and unfavourable that influence attitudes towards thinking: good or bad; and the methods of improving it. Then he poses problems for the development and improvement of thinking in a manner which have direct implications for the effective teaching of school subjects, comparable to that of 'Operational Research' or 'Museum of Defects', the two popular key concepts in industry. He asks: "Suppose we were to make an inventory of basic operations in thinking - how would it look" ? "What basically is at hand" ? "Could the basic operations themselves be enlarged, improved and then be made more productive ? Lastly, he tried hard to

distinguish between structural and non-structural solutions when he discussed some problems relating to paralellograms, sum of the angles of a polygon and summation of series which are well known in the literature. In this thought provoking discussion, it remains unclear how the non-structural solution changes into a structural one, for Koffa rephrases this problem again when he says, "How does a problem find its solution, how does the stress set up by a question contrive to create those conditions which make the answer possible" ? He adds further : "The problem of the arousal of a new process is not in all cases a problem of traces". The immediate cause is still shrouded in mystery for this problem has been duly recognized by Wertheimer, Dunoker, Maier & Claparede (2).

Definitions

of

Problem Solving

Terms like concept formation, critical thinking, creative thinking, reasoning, insight and learning tend to complicate the definition of problem solving. So we have deliberately avoided the use of these terms. Now consider the following three definitions of problem solving :

(a) It may be defined as a planned attack upon a difficulty or perplexity for the purpose of finding a solution. There is then a recourse to reflective thinking which is a process of careful conscious, consideration of facts, beliefs or other elements of mental experience for the purpose of arriving at rational conclusions relevant to some problem or perplexity.

(b) It is a process of raising a problem in the minds of students in such a way as to stimulate purposeful reflective thinking arriving at a rational solution. Three elements seem to be involved here : a situation which presents some difficulty, perplexity or doubt requiring solution, a goal or an end involving some aspect of the situation for which no ready answer can be given and desire or motive that stimulates an attempt to find the answer.

(c) Problem solving takes place when a problem solver accepts to solve it as well as when his previous knowledge or patterns of behaviour are insufficient or inappropriate to enable him to provide an acceptable solution. In such as case, solutions became possible only when he acquires new knowledge or capitalizes upon relationships which have not been seen earlier.

There are all sorts of problems : theoritical, experimental, essay type, objective based as well as objective type, verbal as well as non-verbal (particularly speaking, performance type), breaking the code type as well as anagrams; and lastly those which are nearly impossible to solve. Edison once engaged a mathematician to find out the volume of the bulb theoretically, and verified the same himself by immersing it in a large cylinder. There are also problems which intentionally invite wrong answers. Equally interesting are ten age- old problems which have survived over centuries and have satisfied the intellectual curiosity of man. There

are also problems which mathematicians and scientists put to each other for the benefit of generating knowledge in the years to come. Ramanujan is, for example, the single top most mathematician which the world so far has produced. There are, lastly, those problems which are ill defined and have need to be well formulated for solution. The psychologists, for example, choose those problems which have clear-cut solutions. Here, Piaget is the top star whose problems continue to fire the imagination of children for years, for instance, his conservation problems.

Stages in problem solving :

It is not difficult to find stages in problem solving. Over the years, these have acquired the psychological status. This has enabled teachers and others to take children from the lower stage to the higher stage, and, so on, during the course of problem solving. Problem solving takes place in stages within a certain context. Teaching for problem solving in a context free situation has proved to be futile. It is preferable to use these stages in problem solving for developing the problem solving cycle. It is time consuming but the knowledge so generated is of lasting value and, at the same time, is comparatively speaking, less loaded. To illustrate :

(A) John Dewey (1910)

(i) A felt difficulty
(ii) Its location and definition
(iii) Suggestion of possible solution
(iv) Development of reasoning of the hearing of suggestions

(v) Further observation and experiment leading to its acceptance of rejection.

(B) George Humphrey (1948)

Directed thinking involves :

(a) A Problem Situation
(b) Motivation factors
(c) Trial & error
(d) Use of association & images
(e) A flash of insight
(f) Some application in action.

(C) Polya (1957)

POLYA'S STAGES INFORMATION PROCESSING TRANSLATION

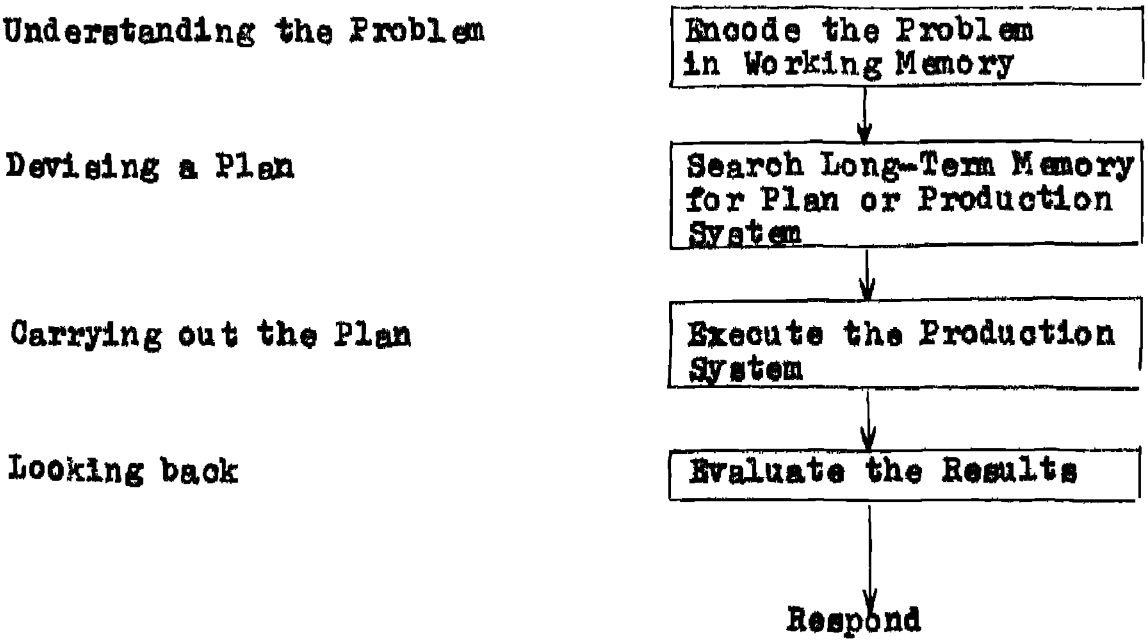

Understanding the Problem
Encode the Problem in Working Memory
Devising a Plan
Search Long-Term Memory for Plan or Production System
Carrying out the Plan
Execute the Production System
Looking back
Evaluate the Results
Respond

Fig.

(D) Mills & Dean (1960)

a) A difficulty is recognized
b) The problem is clarified and defined
c) A search for a clue is made
d) Various suggestions are made and are evaluated and tried out.
e) Whereas practice in the definition of problem involves problem survey, problem description, problem discussion, problem limitation, planning for action and further analysis and limitation (3).

If problem solving is regarding as a way of teaching and learning and that too in a cooperative context, then stages in problem solving are :

a) Problem survey
b) Problem description
c) Problem discussion
d) Problem limitation
e) Problem for action
f) Further analysis and limitation.

(E) N. Vaidya (1986)

a. The appearance, disappearance and reappearance of the problematic situation.
b. Vague understanding and clarification of the problematic situation.
c. Blunt/sharp formulation of the problem.

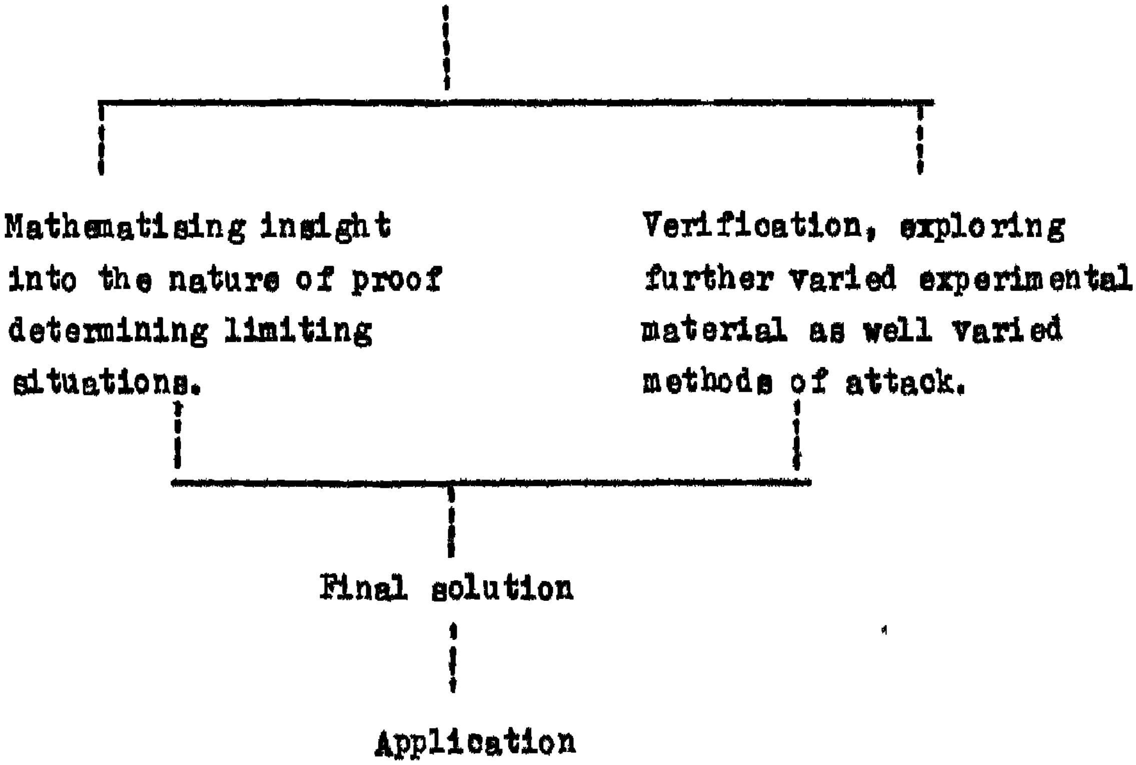
d. Trial and error attacks.

e. Proposing hypothesis.

f. Screening hypothesis and selecting testable hypotheses.

g. Testing hypotheses through control experiments.

h. Obtaining relevant hypotheses.



Mathematising insight into the nature of proof determining limiting situations.

Verification, exploring further varied experimental material as well varied methods of attack.

Final solution

Application

Repetition of cycle in the face of unknown difficulties (5).

What is the real nature or significance of these stages. Like the principles of teaching, these stages do not clarify anything of psychological value. These stages

do, in fact, the job of what we can say, at best, tidying up the situation logically. In other words, they are, in fact, only the highly simplified as well as idealised versions of what may actually happen during the course of problem solving or reflective thinking. These stages are more in the nature of heuristic methods rather than logical proofs. If we try hard to succeed, they help us to see the problem a bit more transparently. Karl Duncker consolidated the gains of the steps and termed them as his "Search Model" which on analysis and reflection turns out to be of omnibus type. The work of Edward-de-Bono is a case in point. To continue his search model may be slightly different from strategy and key factor as, later on, propounded by J.S. Bruner et al; and J.P. Guilford and his workers who termed it so as if determining the efficiency of creative thought. Productive thinking, an aspect of thinking as defined by E.A. Peel is a better term and is much nearer to the ground in comparison to other terms. It takes place when the attack on the problem is taken beyond the stage of explanation and the information so gained is used to transform the problem so that the original is removed. To reiterate, it enters every school subject to a varying extent. The main distinguishing characteristics of productive thought are :

(i) Its inherent element of forward thinking;

(ii) Its potentiality of rephrasing the problem in its soluable form;

(iii) and lastly, its potentiality to solve those problems which were not anticipated.

In sum, the views of Polya and Vaidya sufficiently inform us about capturing the essence of scientific thinking as well as the acquisition of scientific methods on the part of the growing children. They also inform us that it is not easy to promote teaching for logical or scientific thinking in our schools especially when the teacher invariably insists on the correct answers and only correct answer.

The illustration of problem solving
through
The scientific study of a Candle
a
Student-teacher partnership

It is within the reach of many schools to provide training in scientific observation and thinking through cheap materials. In this context, the scientific study of a candle provides immense exciting and educational possibilities. Science students can be easily familiarised with the following scientific phenomena: melting of a solid to liquid, absorption of liquid through material, conersion of liquid into gaseous material, condensation of vapours into liquids, absorption of heat to bring about the change, evolution of heat, oxidation and burning. In the beginning, it is not just sufficient to tell them to watch a burning candle and record as many observations on it as they can. The reason for this is that our science students are not trained to make significant observations unaided. Secondly, for them, this will be an act of observation without direction. It pays dividends if this

approach is slightly bent, that is, through a series of large number of questions requiring short answers, a science teacher can direct his pupils' attention and pinpoint their thinking on certain aspects of the candle : physical appearance, structure and composition of the candle, finding interesting facts and making observations when the candle burns and even identifying the products of combustion. Pupils may arrive at their answers through one or more than one of the following ways : direct observation and measurement, testing ideas through additional experimentation in a variety of ways, setting up a control experiment, if necessary, drawing a diagram and checking for the details and even reading about the question in the textbook and the reference material.

The quality of the work does not suffer if the class is divided into small groups. The questions may be, then, answered by the small group as a whole. Effective learning among the members of the group will take place if they themselves care to resolve their conflicting observations, opinions and arguments. Working along these lines will intelligently inform them that the scientific statements are true under certain conditions. As the conditions change, so change the scientific inferences and, hence, the necessity for making observations under controlled conditions. In this approach, teacher's role is anti-conventional. He does not lecture or impart direct information. He leaves the stage and remains in the background. But, at the same time, his management of the teaching, learning process is not passive at all. He goes from group to group, discusses their difficulties, helps them to solve their difficulties, helps them to solve their difficulties, suggests relevant reference

material, checks their progress and organises critical discussions among the pupils on the basis of experimental results.

This approach, if employed, has the following advantages :

1) Students themselves are active in collecting and interpreting first hand observations. Thus, they are themselves responsible for their own learning. This has the added advantage, that is, this procedure leads to the formation of positive as well as the habits of self-study and self-education later on.

2) Students can easily develop various aspects of the scientific skills, namely, abstract, concrete and communication, etc.

3) It provides ample opportunities for personal exchange of experience among students, strengthening, thus, the pupil-teacher contact in the process. The teacher, thus, gains insights into how the minds of his students work.

4) Through suitable choice of questions and activities, a teacher can summarise and conclude the entire unit which, in the end, will lead to the effective acquisition and retention of knowledge and skills.

5) Classroom teaching is easily and imaginatively linked with home, laboratory and the library. Some students may take up projects with focus on discovery which will familiarize them with the 'stuff and operations' of science.

6) Students grow in problem-solving abilities and develop desirable personality traints like persistence and self-confidence in the face of frustration. They, thus, learn the importance of individual work and opinion, group work, co-operation, sincerity, emotional stability and intellectual honesty. Further, they know that the facts are more sacred and deserve greater respect than the individual scientists irrespective of their social and professional status.

7) A teacher can achieve varied objectives for various categories of his students at different levels of treatment right throughout the school.

First Lesson

Motivating the Students

It is a paradox that, even in the age of atom, most of our homes depend upon candles when all of a sudden and without notice electric current goes off. We also use them at many special occasions like the celebration of birthdays and other festivals. I am sure, therefore, that everyone amongst you has lighted a candle. (If found necessary, a candle can be shown). Informally speaking, you may have made many observations about it. Even if not, I will ask you to write down as many different observations as you can make about a candle when it is not burning and, secondly, when it is burning. I am writing down a few examples to guide your thinking :

(1) It is long and cylinderical in form.

(2) It can be broken by applying small force physically.

(3) It is not soluble in water.

(4) ___ ___ ___ ___ ___ ___

(5) ___ ___ ___ ___ ___ ___

(6) ___ ___ ___ ___ ___ ___

(7) ___ ___ ___ ___ ___ ___

(8) ___ ___ ___ ___ ___ ___

(9) ___ ___ ___ ___ ___ ___

(10) ___ ___ ___ ___ ___ ___

Through a guided discussion, it is possible for the teacher to help the students to write a short note on the candle covering most of its physical properties. This fixes the object of investigation (candle here) for further investigation.

Second Lesson

Materials Required

Pieces of wax obtained from a candle, a few candles, match box, beakers and bottles containing dilute hydrochloric acid, sulphuric acid, sodium hydroxide, chloroform and carbon tetrachloride. Any other material demanded by the students.

Procedure

Students will be asked to answer the following list of questions (questions can vary to suit the mental development)

which relate to the structure and composition of the candle :

(1) Have a good look at the (given) candle. Draw a diagram for it.

(2) Measure its length and thickness at different points and show them on the diagram already drawn by you.

(3) Are both the ends of the candle exactly similar ?

(4) Try to see through the candle by placing it in as many different positions as you can think of. Then, find out whether the light can pass through it or not.

(5) What is the effect of NaOH on the wax ?

(6) What is the effect of HCl on the wax ?

(7) Try to dissolve wax into some given different solutions. If necessary, you can also ask for other solutions. Record your observations on each solvent tried by you.

(8) Add other questions.

(9) ___ ___ ___ ___ ___ ___

(10) ___ ___ ___ ___ ___ ___

(11) ___ ___ ___ ___ ___ ___

(12) On the basis of your observations, tell whether wax is organic or inorganic substance. Give reasons for your answer.

At the end of the exercise, the teacher can organize a critical discussion relating to the composition of the candle. Further, students can also be asked to read critically on the nature of evidence required for classifying substance into organic or inorganic category.

Third Lesson

(Study of a Burning Candle)

The same procedure continues. Here, the questions guide students to make significant observations when the candle is burning. Students can be even asked to set up certain experiments, make observations and draw the necessary inferences. Consider the following examples :

(1) What is the colour of the wick before the candle is lighted ?

(2) What happens to the wick when burnt for the first time ?

(3) Watch. What happens to the tapering end of the candle ?

(4) Describe in a few words the shape of the flame as you observed it.

(5) Place three candles of different lengths but, otherwise, exactly similar in all respects on the bottom of a trough. Cover them with a bell jar. See that they do not touch the inside of the bell jar. Now, remove the bell jar. Light the candles. Replace the bell jar and insert the stopper. Predict which of the candle will

extinguish first and last ? Give reasons. Verify your prediction experimentally.

(6) Take a glass tube about 6 inches long in your left hand and put it one end carefully in the lower most, central and upper most portions of the flame consecutively. Bring a lighted splinter near the other end of the glass tube in case of the above mentioned positions of the glass tube. Observe. Write, what happens in each case.

(7) Put off the candle. Immediately take a lighted splinter and keep it at one mm. away from the wick. See, what happens.

Evaluation

Questions and problems like these or similar to these can be used both for instructional and testing purposes. Quality is, thus, built into instruction as well as into evaluation for the main burden of forming the concept or finding the answer through thinking and action (hypotheses setting and testing) falls on the student himself (6).

Listing some problems
for
stimulating thought

We have already appended the Piagetian questionairre for studying logical thought among children and adolescent pupils. Let us list some additional problems which have a stood the test of time. These are :

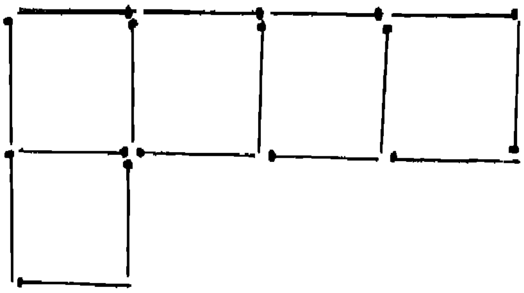


Fig. 2

1. Take fifteen match sticks and make five squares as shown above. Now make four squares by removing any three match sticks

2.

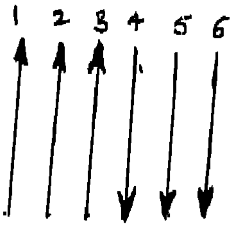


Fig. 3(a)

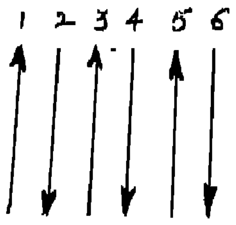


Fig. 3 (b)

Take six arrows in a row. The first three arrows point up and the last three point down. Your problem is to obtain the arrangement in fig. 3(b), that is, the adjacent arrows must point up and down alternately. You can touch the two adjacent arrows at the same time. The number of moves should be the minimum.

3.

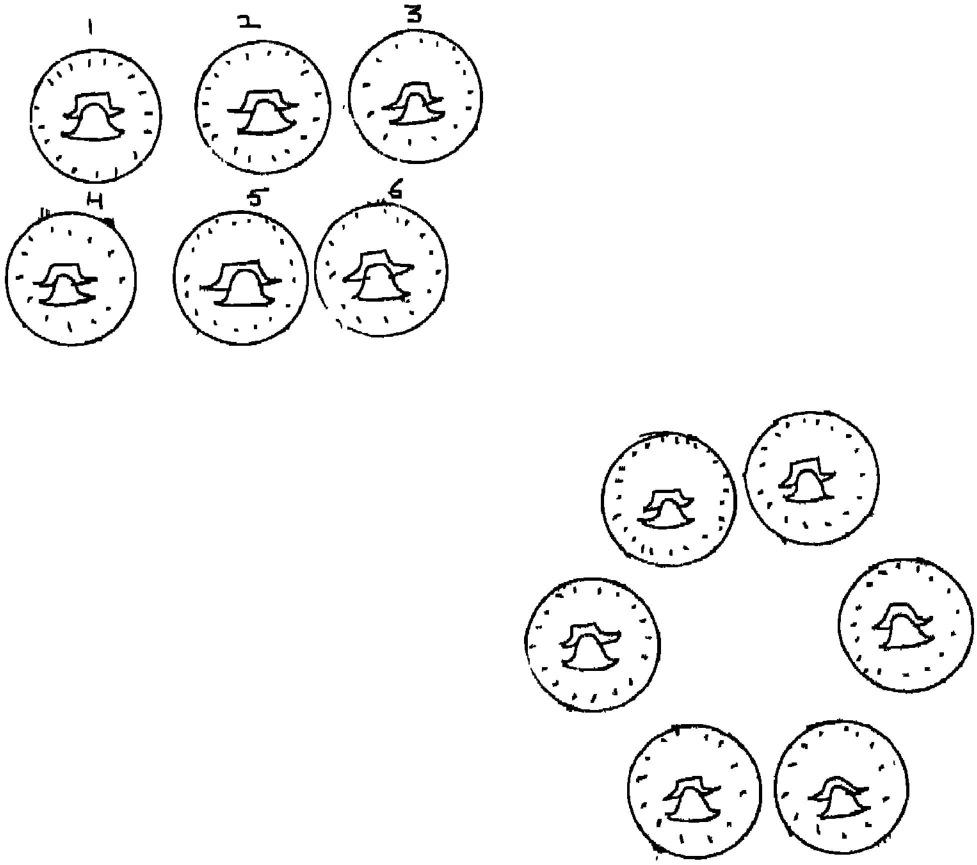


Fig. 4

See the arrangement of 6 coins above. These touch each other (up, down and the sides). Your problem is to obtain the arrangement on the right by moving exactly two coins. Specify your procedure.

4.

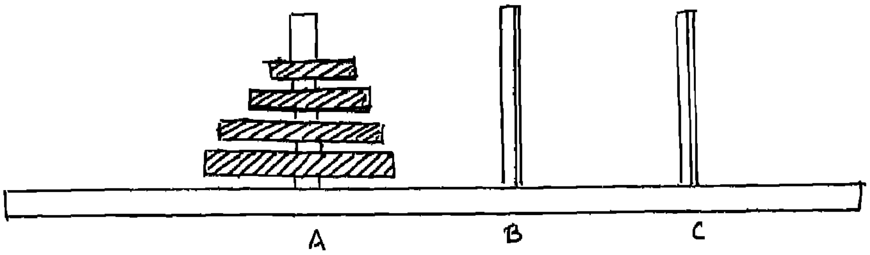


Fig. 5

The problem is to transfer the four discs from the peg 'A' to the peg 'C'. You are free to take the assistance of peg 'B'. You are not allowed to put a larger disc on a smaller disc. For example, you can not put disc 2 on disc 1.

5.

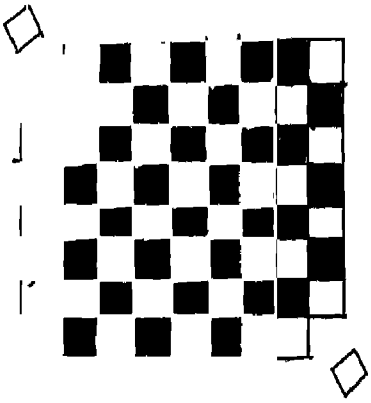


Fig. 6

Have a look at the above checkboard which contains 32 dommoes where each of the dommoes covers two adjacent spaces. So the total number of spaces (adjacent squares) is 64. Now cut off two of the squares as shown above. The problem is to place the 31 dommoes on the board so that the remaining 62 squares are covered. If so, how? If not, why not ?

6.

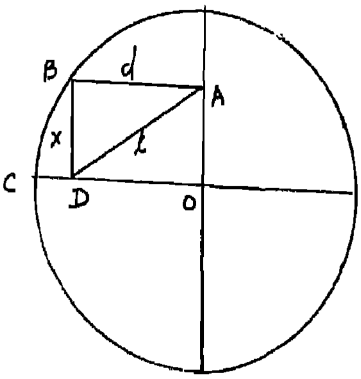


Fig. 7

The diameter of the circle is 10 c.m. The problem is to find the length of AD. If you cannot, join BO.

7. Let us here list another set of four problems. Here, it is a case of polarized thinking, i.e., functional fixedness or rigidity of the thought. If one looks at the problem from one angle alone, he fails to see the same problem from another angle. It is a phenomenon of temporary nature.

8. one who sees Configuration no 1 is unable to see the Configuration no 2 and vice versa.

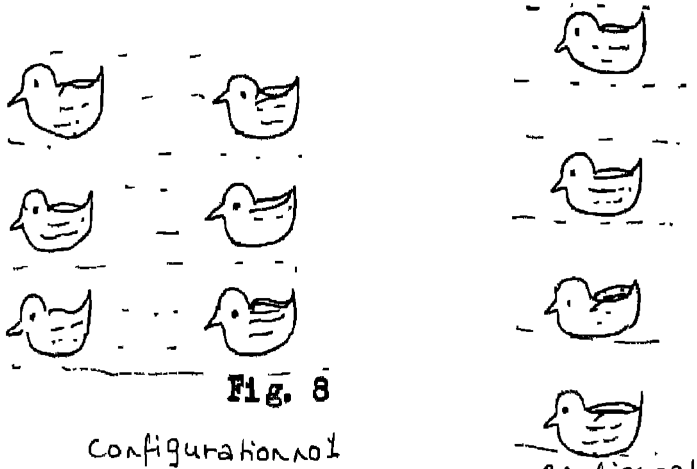


Fig. 8

Configuration no 1

Configuration no 2

(i) There are some ducks swimming in a single file under a bridge. Two are in the front, two are in the middle and two are in the rear. Find the number of ducks. The number of ducks should be minimum.

(ii) Two train stations are fifty miles apart. At 2 PM one Saturday afternoon two trains start toward each other, one from each station. Just as the trains pull out of the stations, a bird springs into the air in front of the first train and flies ahead to the front of the second train. When the bird reaches the second train it turns back and flies toward the first train. The bird continues to do this until the trains meet.

If both trains travel at the rate of twenty-five miles per hour and the bird flies at a hundred miles per hour, how many miles will the bird have flown before the trains meet ?

(iii) Your goal is to measure out exactly 100 units of water from an unlimited source of water. The only tools you have to do this are three pitchers, Pitcher A which will

hold 21 units of water. Pitcher B which holds 127 units, and Pitcher C which holds 3 units of water. Describe the sequence of filling and pouring that would be necessary in order to measure out the goal amount.

Problem	Pitcher A	Pitcher B	Pitcher C	Goal
1	21	127	3	100
2	14	46	5	22
3	18	43	10	5
4	7	42	6	23
5	20	57	4	29
6	23	49	3	20
7	15	39	3	18

Luchins' (1942) water-pitcher problems

Rigidity :

Both of these problems illustrate different forms of the first phenomenon of problem solving we will discuss, that of rigidity. This refers to the fact that people often fail to see adequate solutions for problems, because they fixate on only one way of viewing the problem.

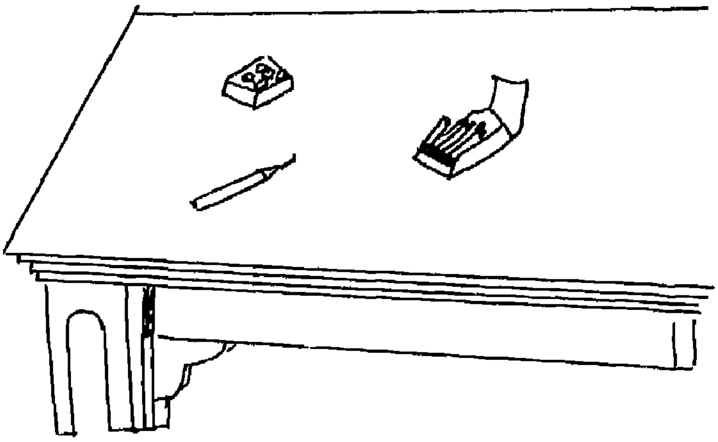


Fig. 9
One version of Duncker's (1945) famous problem. Figure out how to mount the candle vertically on a plywood wall, so that it will act as a lamp.

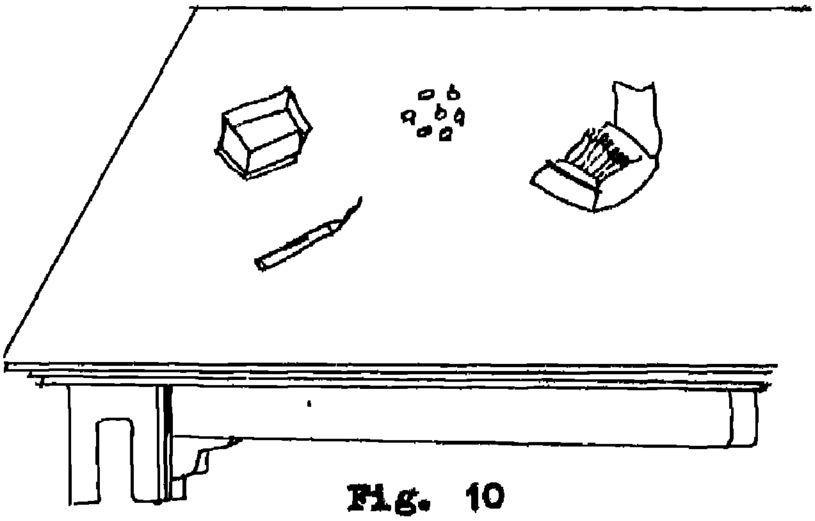


Fig. 10
A second version of Duncker's (1945) famous problem, designed to help the problem solver overcome functional fixity.

Here, the problem is : how to mount the candle vertically on a plywood wall so that it will act as a lamp. Figure helps in finding the solution. It is a case of rigidity of thought, where one only sees the box containing sticks only as match box rather than its use as the platform for the candle. There is no end to such thought provoking problems. In a way, these problems train us to see a problem under study from every possible angle. If so, a problem tends to construct as well as reconstruct its own solution. Lastly, the experience of problem solving is highly instructive and educative (1).

Concluding statement

The field of problem solving is vast. It is precisely for this reason that the definitions of problem solving vary very widely right from puzzle solving through concept formation tasks to creativity (production of novelty). There are no rules which guarantee solutions to the problems. These simply amount to generating problem precautions and sensitivity. Any finding that is obtained has to fight for its survival in literature. It needs to be tested under diverse conditions. If found true, it strengthens the base of our knowledge. The discoverers of knowledge have their own individual tales of personal difficulties, frustrations, jealous, unsupportive environments and ecstacies. Such biographical descriptions and details give inner strength to those who commit themselves to life long research plans. Anyone who short circuits this path is invariably bound to end in failure or ridicule. To illustrate : A chemist wanted to solve a difficult research

problem. He failed and following the foot-steps of the great scientist, say, Archimedes went to the bath room. He went into the bath for days and nights. He only discovered at the end of this exercise that his towels were wet.

Lastly, the school and home have to play a supportive role. They should lead children to see the relevance of their responses. If done, children are in a position to improve upon their answers through experimentation, personal reading and reflection, debates and discussions, of course, not excluded. There is no substitute for such activities of the mind, for problem solving is both a risky and creative activity. It haste snatch knowledge, however, small it may be from nature. Ket us end this account in the words of Michael Oakeshett :

> Men sail a boundless and bottomless sea, there is neither harbour for shelter nor floor for anchorage, neither starting place nor appointed destination. The enterprise is to keep afloat on an even keel; the sea is both friend and enemy; and the seamanship consists in using the resources of a traditional manner of behaviour in order to make a friend of every hostile occasion. (8).

3

The Piagetian Concept of Knowledge

- Introduction
- Concept of Piagetian knowledge
- Assumptions underlying the Piagetian concept of knowledge
- Some other Approaches to the study of Cognition
- Concluding statement

We only now need to recall the fate of the principle of inertia in the ocudential world. After it was "discovered" during the period of Galelio, Descortes and Newton, the principle was alternatively considered as rather absurd and difficult to accept, as entirely evident and needing no explanation and much later, as a principle that is neither evident, nor right, nor wrong, nor absurd, but rather a regulatory principle within a certain structure of a theory of Mechanics. This proves beyond any doubt that the acceptability of a principle, such as the principle of   is linked in a very fundamental way to the whole conception of the world or, at least, to the conception of the particular branch of science to which it belongs, this in turn being linked to a particular society in a particular period of its history.

Rolano Gracia

in

Developmental epistemology and fundamental problems

in

The Theory of Knowledge

Introduction

Some background renderes :

In the history of our civilization, there have been quite a few exceptional men who have sought happiness in the republic of learning and scholarship. Nay, they have lived passionately and fully; and that also singularly for advancing knowledge, the late professor. Jean Piaget being no exception. The reason is that they put to themselves questions of universal interest and significance. He tried to forgo ahead his thought in every possible direction. He presented a vast epistomogical frame of reference for understanding changes in knowledge at increasing levels of validity. He spent his entire life in explaining it but to no avail. His entire experimental work was the function of his genetic epistomology. Professor J.H. Flavell also erred at this point. It was a sort of "Cart before the horse situation" which immensely worried Piaget throughout his life. Contrary to the spirit of Science he used unscientific methods in his highly varied accomplishments. He, however, made an exception in his studies on perception. He continued to handle his own ensuing confusion single handed in the light of sharp forthcoming criticism. With his vigorous brain power and long hours of sitting at his desk for about fifteen hours a day for over sixty years, he began to solve an age-old problem of true knowledge. He strained himself very hard in stating clearly the very source of confusionfor the benefit of his readers. According to him, considering the

short history of psychology, less than hundred years old, it has to solve its own definitial problems first in more or less the same manner as was done by the naturalists, priests turned scientists or the other way round, inventors, technologists and scientists. It is to be stressed that the birth of the "Tribunal of experimental Science" in the seventeenth century was not an ordinary event.

Jean Piaget drew heavily from this great philosophical reservoir by presenting a series of challenging synthesis as obtained in the rational tradition of plato : mental categories of I. Kant, the Bergsonian notion of perceptial changes, the enhanced and the quick mobility of Gestalt structures; and the use of symbolic logic for the analysis and interpretation of thought in terms of seriations, classes, relations, reversibility, equilibrium and groupings. He, while still remaining a firmer speculator, investigate an age old philosophical problem experimentally by posing it as follows -

> How and when can man be sure that his knowledge is true knowledge, when time and again he finds that what he took to be knowledge has proved to be error.

Piagetian concept of knowledge :

Piaget raised the questions or problem to an epistomological status and posed it in an experimental form. He did not aim at suggesting a conventional sort of

answer. He also threw a bridge between philosophy and biology by placing psychology somewhere mid-way between these two fields of knowledge. He provided a biological base to his theory of knowledge. He saw intelligence as a developing phenomenon. Cognitive development became a sort of open paradigm as a scientific methodology and practice. It also became a dynamic process influenced further by maturation, environment and the ongoing attainment of equilibration at all levels of intellectual development. It was not an easy enterprise for he had to develop not only highly ingenious research techniques but also highly controversial symbolic logic for explaining now the house of knowledge is build up by the child in his head not a particular child but any child anywhere in the world regardless of highly diverse circumstances of living. Jean Piaget in a series of lectures in the united states of America defined genetic epistomology somewhat as follows -

> Genetic epistomology attempts to explain knowledge and in particular, scientific knowledge on the basis of its history, its sociogensis and especially the psychological origins and operations upon which it is based.
>
> All epistomologists refer to psychological factors in their analysis, but for the most part their references to psychology are speculative and are not based on psychological research. I am convinced that epistomology brings up factual problems as well as formal ones, and once factual problems are encountered, psychological findings become relevant and should be taken into account.

> The first principle of genetic epistomology, then, is this - to take psychology seriously. Taking psychology seriously means that, when a question of psychological fact arises, psychological research should be consulted, instead of trying to invent a solution through private speculation.
>
> So, in turn, genetic epistomology deals with both the formation and meaning of knowledge. We can formulate the problem. By what means does the human mind go from a state of less sufficient knowledge to a state of higher knowledge. Our problem from the point of view of psychology and from the point of view of genetic epistomology is to explain how the transition is made ... ... The nature of the transition is a factual question. The transitions are historical or psychological or sometimes even biological.

He saw knowledge as a structure - a relational structure. It determines our perception and understanding of our world. Genetic epistomology is a branch of philosophy which deals with the nature and formation of knowledge. Scientific knowledge in particular.

It can be represented pictorially as follows :-

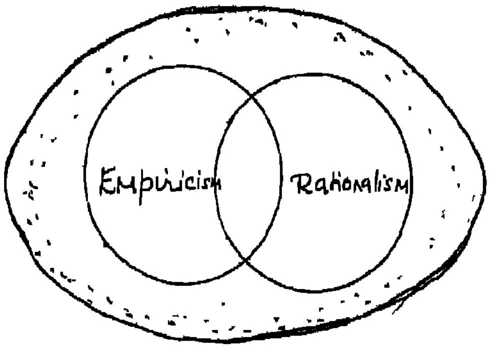


Fig. 1
Piaget's theory embraces both Empiricism and Rationalism

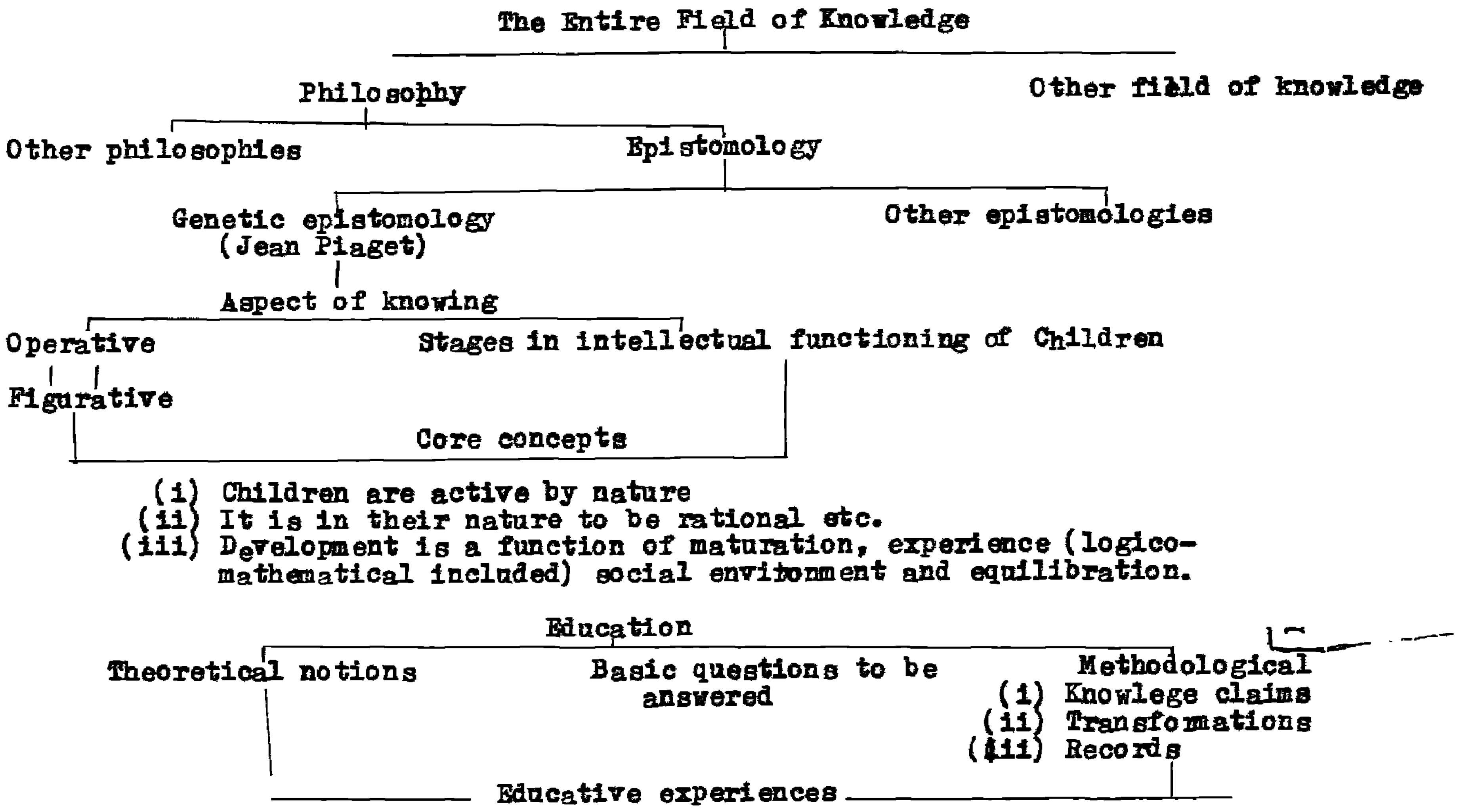

The Entire Field of Knowledge
Philosophy
Other field of knowledge
Other philosophies
Epistomology
Genetic epistomology
(Jean Piaget)
Other epistomologies
Aspect of knowing
Operative
Stages in intellectual functioning of Children
Figurative
Core concepts
(i) Children are active by nature
(ii) It is in their nature to be rational etc.
(iii) Development is a function of maturation, experience (logico-mathematical included) social envitonment and equilibration.
Education
Theoretical notions
Basic questions to be answered
Methodological
(i) Knowlege claims
(ii) Transfomations
(iii) Records
Educative experiences

Fig. 3 It shows the position of Genetic epistemology within the educational context

The assumptions underlying the Piagetian Knowledge :

It is essential to keep the Piagetian framework of genetic epistomology in mind. It is a tough job to understand it because he did not care to clarify it more than it was necessary. Piaget concentrated on the knowing aspect of consciousness, namely, intellectual development. Assumptions made in the field of biology equally apply to cognitive development. These are as follows :-

A. Children are active by nature. It is in their nature to learn and go on learning. As a corllary to it, it is in the nature of thought to move forward inside the directionless and pathless territory of unknown thought.

B. The biological principles of organisation and adaptation (assimilation and accommodation) provide stable as well as dynamic mechanisms for intellectual growth.

C. Higher mental processes evolve out of lower mental processes. In other words intellectual thought is hierarchically determined, the two cognitive structures being scheme and operation.

The main features
of
Developmental epistomology :

Following are the main distinguishing characteristics of Piaget's genetic epistomology :-

1. It has strong interest in studying changes in scientific knowledge. Barring a few exceptions here and there, individual developments of various sciences move towards integration and in short general systems.

2. It is possible to delimit any philosophical development considerably for seeking an experimental solution.

3. There is nothing sacred about scientific knowledge because it can be challenged at any point by the imaginative minds.

4. It is, unlike the classical epistomological theories, more essentially a process rather than a product or even fact. This view enables knowledge to be studied in a dynamic rather than a static manner. It is than simply a case of continuous construction where knowledge at a higher level of validity evolves from knowledge at a lower level. It fulfils a natural human need of longing to know, understand and explain things. Thus Piaget has tried to show that constructivism is the only possible epistomology.

5. It is an effort to arrive at truth rather than possession of it by the methods of verification, however, complex these may be within the epistemology of one's Science.

6. It attempts to maintain a firm distinction which is usually ignored between epistemological subject and the individual subject. The latter is particular individual having a distinct personality. For reaching statistical results of a generalised nature, individuals have naturally to be sampled. The former, on the other hand, is a subject of universal nature or interest having general coordinative actions which, later on, become the basis of knowledge with the operation of the following trilogy - reflection, deduction, experimentation.

7. It is tightly woven abstract theory difficult to apprehend but, at the same time is internally quite consistent. Intestingly enough, it emancipates itself from perception and provides accounts of development which is explorable experimentally in diverse fields of knowledge.

8. It sees psychological development similar to biological epignosis which imples :-

   (a) There is a causal sequance of events. It is not of unear increase in nature but instead possesses differentiation, complexity and organisation.

(b) It is a case of growth step by step. These steps follow each other in an invariant manner. It is this interpretation which has been found working and becomes suspect in the eyes of some logicians.

Lastly it is worth stressing that the experimental work of Piaget is a function of his genetic epistemology and not vice versa. It is an abstract frame of reference where he further distinguishes three distinct periods of history of epistemology, namely, meta scientific epistemology, para scientific epistemology and scientific epistemologies. The last mentioned epistemologies take a critical attitude to part of the whole reality.

Some other approaches
to
The study of cognition

It is, of course, true that no study on cognition is complete without direct as well as indirect reference to the Piagetian studies. Other approaches have also appeared, particularly speaking, when cognition is seen, as it ought to be seen, within the life span perspective. It is an exciting enterprise to work on cognition in our context, and interpret the obtained results in another context. According to Marion Perlimutter, the cognitive developmental psychologists should address themselves to the following two major problems, namely, the change of cognition with age; and

the causes of such changes. He then describes as well as evaluates such researches and finally, presents a three tier model of cognition within the multi-disciplinary context for the human organism (See Fig. 4). Returning to the cognitive approaches, these are :

(a) Organismic approach (Piaget and Basseches)
(b) Mechanistic approach (Siegler and Salthouse)
(c) Contextual approach (Vygotsky and Baltes)
(d) Psychometric approach (Binet and Horn)

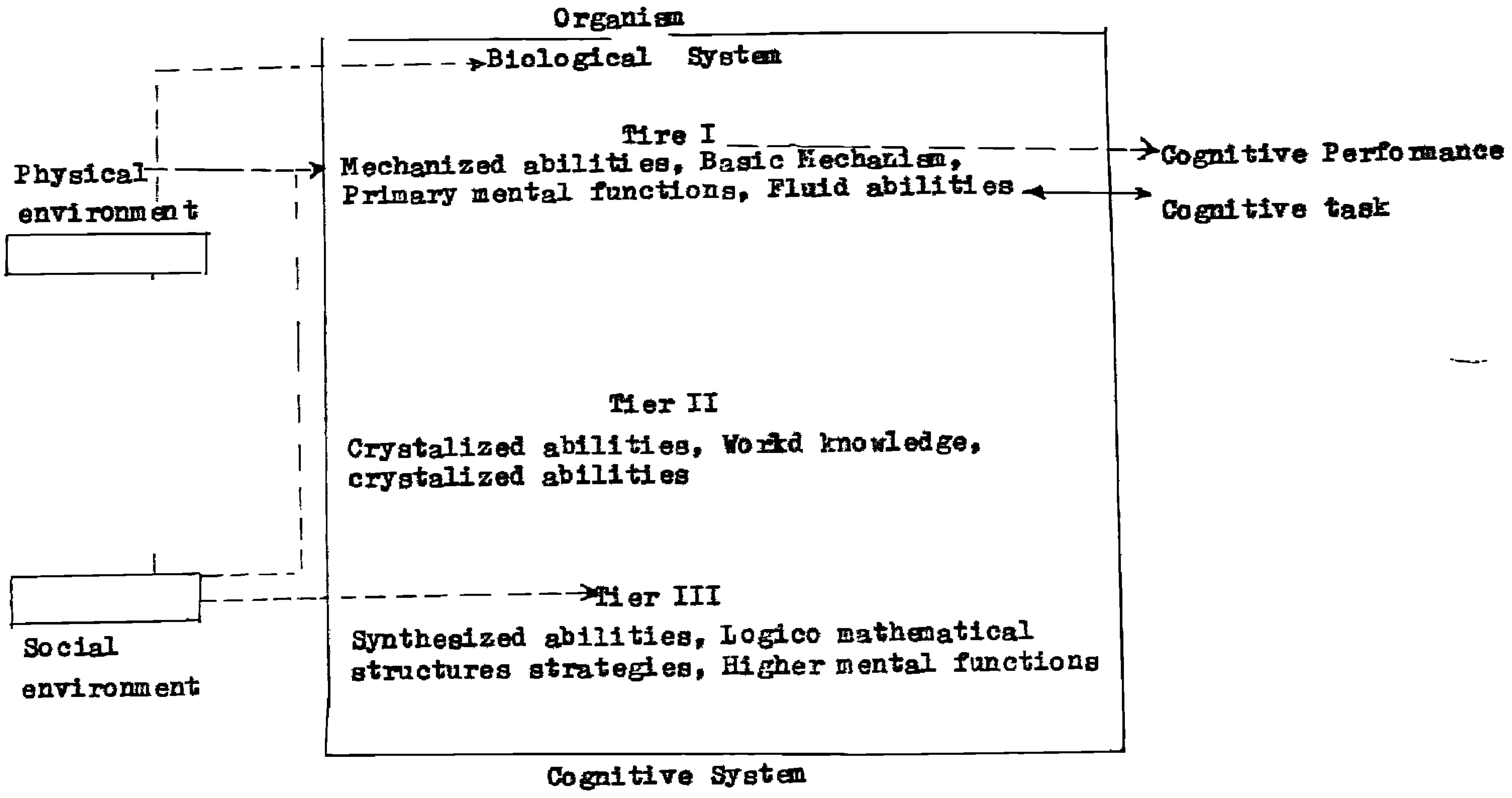

Organism
Biological System
Tire I
Mechanized abilities, Basic Mechanism,
Primary mental functions, Fluid abilities
Cognitive Perfomance
Cognitive task
Physical environment
Tier II
Crystalized abilities, World knowledge,
crystalized abilities
Social environment
Tier III
Synthesized abilities, Logico mathematical
structures strategies, Higher mental functions
Cognitive System

Fig. 4 Shows the three tier model of Cognition (adapted)

Let us present in the tabular form the nature of cognition and development for each of the four approaches :

S.No.	Assumptions	Organismic	Mechanistic	Contextual	Psychometric
1.	Nature of Cognition				
	a) Generality : intra-individual	Holistic & Universal for species	Elemental Universal	Holistic specific	Elemental Universal for culture specific
	b) Inter individual	Universal	Universal for cultures	—	—
2.	Nature of development				
	a) Form (direction)	Qualitative Unidirectional	- do -	Qualitative Multidirectional	- do -
	b) Rate (End state)	Fixed Closed	Plastic Open	- do -	- do -

What is Cognition ? At least, it is not a single entity, an unchanging one like the physical constant in Science. It includes perception, memory, intelligence, reasoning, judgement and decision making. It enables us to think, act and know about the world. Conceptualize and interpret experiences, to maintain a sense of self or direction and communicate with others. It consolidates, aggregates and enhances individual competencies with a view to negotiate varied bends in problem solving. This entire frame-work is widened, deepened and scope of investigation enhanced when all age - related changes in cognition are called cognitive development. The position of Piaget is well known. What will be his position like when data collected within his framework are examined in the remaining three frameworks. Naturally, the strength of the finding changes from framework to framework. This in a way ought to be the main function of any science and, particularly speaking, the educational science should not far lag behind. Otherwise, how is light likely to be thrown on the nature and function of mechanisms underlying cognitive behaviour within the context of biological, psychological and sociological factors, functioning of biological constraints; systematicity of school influence; personal construction and reconstruction of knowledge; and lastly, the controllability of psychological factors ? More specifically, what is the crux of the problem across the four cognitive approaches ? It is to examine the role of :

(a) Stimuli (meaningful versus meaningless)

(b) Task (Complex versus simple)

(c) Content (rich versus impoverished)
(d) Ascent of abilities (prenatal versus early childho ..

What about the nature and development of abilities across the four cognitive approaches ? Evidence, largely speaking, indicates that with the possible exception of logico-mathematical structures, primitive abilities comprising basic mechanisms, primary mental abilities and fluid abilities are rooted in biology. The other intermediary abilities such as world knowledge, crystalized abilities, strategies and higher mental functions are rooted in experience. If this view is accepted, then it is not difficult to develop a three tier model of cognition as shown in the adapted fig. 4.

Final remarks

Cognitive development when studied across these four approaches with appropriate intervention programmes provides an excellent base for the development of teaching learning strategies efficiently. It gives meanings to terms such as : functional fixedness, insight, hierarchical nature of knowledge; and principles of teaching such as :

Teach organically or scientifically.

If that is the case, a part finding obtained in one framework cannot rule as weel as over-rule the obtained main finding across the for spectrum of the cognitive approaches. Why ? The main finding, of course, questionable

exists within the context of cognitive development on its own status as part of the basic knowledge when seen historically, culturally, ecologically and even semantically. Like agriculture, education has its own dignity; and that too, independent of its theory with a long tradition of teaching and learning. Pre-suppositions or assumptions underlying it are to be tested for productive results. It is thus kind of task, in fact, a major task which ought to be approached by our researchers and teacher educators at all levels of education. It is of no use talking in generalities, or, say, independent of contexts, on teaching learning strategies. Saying cryptically, it is a futile exercise to carry out where a deaf person is talking intellegently to the dumb person who, in turn, is communicating with the blind person. It is stressed firmly that there are many pathologies in the business of education. Frankly speaking, our collective response to educational pathologies amounts to collective chaos rather than collective quest. Ours is a country where everything in the name of active as well as productive education/educational methodology is loosened to dust earlier gradually; and now quickly. It is a country where academic heroes of abject stupidity as well as zero multipliers, like the solar eclipse, rule the educational hierarchy spawning nervousness, confusion, degradation, darkness and inefficiency of all sorts. Lastly, whereas the moral dimension to education is getting eroded gradually, the psychological dimension to the education hardly had any survival chance in our country. Still hopefully, we would like children going to school happily and more happily in the years ahead.

A Survey of Studies
On
Problem Solving in Science

Theories about learning go back to the Greeks. Plato saw learning as the uncovering of innate knowledge such as language skills and mathematical ability.This 'rationalist' notion of learning lies behind contemporary assertions that some people are 'academic' while others are'practical and technical'. In contrast, Aristottle held what is today known as a 'behaviourist' theory. This asserts that we learn that we come to associate the commom features of thinkgs we encounter into conceputual categories such as 'tables', 'pupils' or 'research reports'. More recent 'constructivist' theories also assume that learning arises from experience. However, they question whether the process is as straightforward as associating stimuli with particular single concepts. Instead, they argue, we constantly assimilate new instances of concepts into schemata. With experience, our understanding becomes more sophisticated. A practical consequence of constructivist thinking for the classroom is the need to take account of individuals' previous learning if teaching is to be most effective.

The problem with each of these theories is the extent to which the evidence used to support them is generalisable. There is evidence to suggest that certain human skills are innate but little to show that this explains all learning. Animals and humans can be shown to learn by association but the evidence relates mainly to quite trivial tasks and behaviours. The constructivist argument is persuasive but

....2

It is difficult to prove the existence of schemata. In short, the three 'classical' explanations still compete to explain how learning takes place, but offer little of practical value to teachers other than a common assertion as to the importance of motivation.

Harry Black, John Hall & Sue Martin
Quoted in SCRE Newsletter 'RESEARCH IN EDUCATION'
Autumn 1990 - 47

A Survey of Studies

On

Problem solving in Science

Introduction :

Latin Poet Terence once remarked, "Being human myself, I regard every thing to do with human beings as my concern" (1). It is an excellent remark applicable to human thinking, learning, adjustment and attitude. Speaking restrictedly, it can be very safely said that our knowledge about how children learn Science is very little. Yet, it is a fact that learning goes on in a big way among humans and, to a varying degree, animal as well. It may be provoked by new and novel material as well as repeated presentation of the same in different ways, opportunities for practice and individual curiosity. Like Peel, E.A. Lunzer then poses several problems which need to be answered by the researchers which relate to conditions for learning maximally; amount of practice; the nature of learning; the contextual operation of intelligence for example, rapidity in learning, and the nature of difficulties underlying various learning

tasks (2). It is also well known that we least make use of the basic concepts drawn from the various learning theories and the well known empirical studies including action research in our day to day instruction. Even in this decade, no serious and sequential effort has been made to select even few concepts, demonstrate and illustrate them under all possible conditions, for as many school subjects as possible throughout the school period. Research of the practical type relevant to the teaching of various school subjects including Science and Mathematics is little in this country. Even in this scarce literature, ideas lie scattered here and there which when consolidated should help us a bit in relating the mental development of children to the powerful concepts of Science.

Problem solving. It is a difficult to define problem solving because it defies its own definition. It may be regarded as a task oriented situation which begins as the problem is presuented to the problem solving and ends as soon as its solution is obtained. Gestalt psychology is highly relevant to the study of problem solving for it makes use of those problems which have clear

out solutions. The two basic motives underlying problem solving within the context of Gestalt psychology are : productive thought and insight. Let us here refer to the work of Karl Dunoker who stated his main thesis as follows (3) :-

> In the present investigation, the question is : How does the solution arise from the problem ? In what way(s) is the solution of a problem attained ? ... ... A problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever, one cannot go from the given situation to the desired situation simply by action, there has to be resource to thinking. (By action we mean the performance of obvious operations). Such thinking has the task of devising some action which may mediate between the existing and the desired situations. Thus the solution of a practical problem must fulfil two demands. In the first place, its realization must bring about the goal situation, and in the second place, one must be able to arrive at it from the given situation simply through action. At every moment during the course of problem solving, the direction of a solution process depends on the psychological relief map of the problem situation, the disposability and the looseness of the elements constituting the problem.

Let us now illustrate the above thesis with the help of one of the world famous problems as used by the Gestalt psychologists for the investigation of problem solving among the university students.

The Stomach Tumour Problem

There is a patient suffering from an inoperable stomach tumour. Radiation at different intensites is available. The problem is to treat the tumour without destroying the healthy tissues surrounding it. What can be done ?

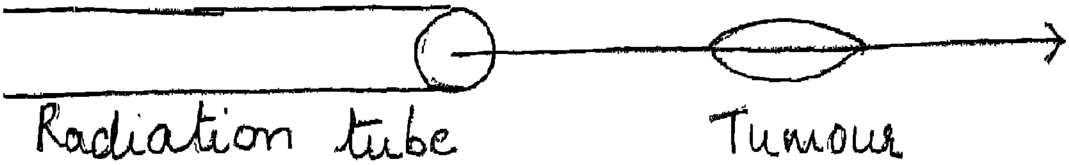


Fig. 1 which presents the world famous stomach tumour problem

Case study approach is employed. The method of procedure is quite simple. The subject is asked to speak aloud all the ideas, both sensible and otherwise, which strike him during problem solving. Further, the subject is free to question the experimenter whenever the former is in doubt or does not feel completely informed about the problem under attack. All the responses emitted by the subject are recorded. This dialogue

continues till the problem is solved partially or fully or when the subject give it up. The following conclusions emerged from his studies :

(I) One solution is as good as any other solution so far as the 'way out' of the problem situation is concerned. What is reflected, in fact, is the degree of acceptance of the demands of the problem. Extraneous considerations enter into the problem situation when the essential aspect of the problem is not grasped.

(II) Dunker then distinguishes between functional solution and the specific solution. The functional solution may be right or wrong. It only reflects the general range of approach or even availability of ideas on a particular problem. At the specific execution of the solution stage, the problem is simply to fill in the minor details only. He then goes on to distinguish between meaningful efrors and stupid errors. The former arise in the specific execution of the right idea and the latter ones arise when the grasp on the problem is either absent or too poor. He is then able to

distinguish between organic solution and mechanical solution by the types of behaviour shown by the types of behaviour shown by the subjects during problem solving (In the final written from the solution, this distinction is very difficult to maintain and Duncker is aware of this difficulty). The organic solution is meaningful, less elegant, long and time consuming where as the mechanical solution is concise and follows a set pattern. Moreover, in the case of an organic solution, one sees clearly the evidence for the analysis of the material. For instance Piaget's work on number shows the concept of mechanical solution in case of children who compute accurately without even understanding the basic ideas, a finding consistent with Jhon Hott.(4)

(III) Generally speaking in the case of a successful solution, each response to the problem situation is in fact the reformulation of the problem developing organically. In prospect, it is the nature of another problem (concretization of the goal) and in retrospect, the formulation of the problem more productively then implies the emergence of one or

more than one functional solutions where nine specific statements leads to the final form of the solution or solutions.

(IV) Cues and hints are only understood when they approach the genetological line under the development, a finding consistent with the law of anticipation as stated by selz. According to it, success favours that operation which 'anticipates the schematic anticipation of the solution' approaching fully its anticipation.

(V) Solution learnt mechanically, that is, without understanding tend to be forgotten in the near future. Past experience then does not guarantee success because the very essential of the problem was not grasped then.

He rejected trial and error learning as propounded by Thorndike and in its place talked of immediacy of insightful solution. Its characteristics according to E.A. Lunzer are : Suddenness of solution, Immediacy and smoothness after solution, Ability to repeat solution without error on successive presentation of original problems and ability to transpose the

solution to situations exhibiting the same relational or structural features, but in a different context (2). He has independently determined the characteristics of insight experimentally and are quite comprehensive Van de Geer appears to have said a last word on it -- "A shift in meaning is apparent. It meant to indicate a specific inner experience, later it was regarded as a certain kind of behaviour and now it appears to be a sort of psychological principle (5).

Varied Studies Surveyed

Historically spearing :

G. Stanley Hall studied the contents of children's minds and thereby emphasised the importance of primary or first hand experience rather than bookish knowledge. He further stated a well known educational principle (known to unknown) "Concepts which are most common in a given locality are the earliest acquired, less frequent ones come later, no one child has all the misconceptic recorded, non is free from them ... ... The fact that children see objects a hundred times without acquiring

consciousness of them suggest that we need to converse with children about common things". (6) Keen studied children's reasoning and found that children under study "weak urge for experimental verification." Children are sure to develop illogical concepts if teacher does not take sufficient care while introducing new experiences to them. Deutsche examined the nature and development of causal reasoning a phase of children's thinking in the context of the Geneva schools with the aid of the problems with and without experiments. She noticed a gradual growth of reasoning in contrast of stagewise growth suggested by Piaget. Secondly she did not find the detailed classification of reasoning into seventeen types useful as found by Piaget. Thirdly school experiences explained specific responses to the specific questions which are suggested had direct and indirect implications for teaching and learning children. (7) Oakes investigated qualitatively children's explanations of natural phenomena and concluded that all age groups regardless of mental ability and grade gave all types of answers. Further adult groups did not follow any definite procedure while explaining

unfamiliar phenomena. Fourthly he did not find a difinite stage in children's thinking characteristics of a given age. (8) He thus confirmed the earlier findings of Dutsche, Keen, Hazlitt, Johnson and Josey Susan Issac and Hung, who had found that both American and Chinese children' gave naturalistic factual and logical explanations of phenomena'. (8) W.H. King, while exploring the development of scientific concepts of children (N= 1235 between 5 to 12 years) with the aid of seventy questions suitably classified into five categories : Length, time direction, volume and weight; mainly mechanical principles, lever, wheels, living things; seasons and shadows concluded;

(a) Children at all ages gave all sorts of responses.

(b) Like Oakes, no stages in causal reasoning as propounded by Piaget were noticed. Responses appeared to be, largely speaking the function of question rather than solely the function of age.

(c) Some children showed difficulty in verbalising their concepts which in fact they had understood as earlier reported by D.H. Russell. He then added : 'Perhaps there is a need about eight or nine years of age for the harnessing of this expensive so that

children of primary school age have accumulated a knowledge of scientific facts and that this knowledge increases with age in some cases steadily. Some of the answers had to be obtained by reasoning on the basis of past experience and these also showed steady increase with age upto eight or nine years. Beyond that, apriori reasoning was not sufficient and adult guidance and explanation seemed essential, at least, in concepts relating to estimation of length, direction, weight and volume. (9)

N. Vaidya investigated several schemes of thought in science among 200 pupils (B = G) drawn from grades VI to X in equal number (B = G = 40) who were controlled on I.Q., age, grade and socio-economic status. Problems were presented individually to the pupils which related to (1) using constant differences (2) using proportion (3) proposing tests (4) stating as well as testing of hypotheses and grasping the essence of the problem.

The main findings of this study indicated that :

(1) Except occasional fluctuations, average performance on each problem increases with grade. Mean performance

in most of the cases favours boys rather than girls. But both of they try to hard to equalise their performance as they move into higher grades.

(ii) A given problem, or a part of the problem or a process in that problem, is solved successfully (or failed) over a wide I.Q. range both within and across the various grades.

(iii) A given problem is solved in stages. It is possible to identify stages in the solution of any problem.

(iv) Unexpectedly, pupil commit a large number of errors while engaged in problem solving. These errors further increase in the higher age group when they fail to grasp the main requirement of the problem. Among these errors, the dominant ones, shared by more than 15 per cent of the pupils, largely speaking, Suffer "a hump" before they finally decline with increasing grade.

(v) Contrary to Piaget, pupils are not in a position to exhaust or suggest all possibilities. Combinations and possibilities. Over three fifths of pupils from grades VI to VIII are badly affected when a problem inheres reversibility in thinking.

(vi) The complex problem solving processes arise from simple thinking processes.

(vii) The role of the nature of the problem being critical in investigating thinking. The adolescent pupils contrary to Piaget, are affected to a great extent by the content of the problem.

(viii) Adolescent pupils are in a position to set up hypotheses but not in a position to test them which shows that their minds have not become experimental. Most of the adolescent pupils possess schemes of proportion as well as generalisation to algebric symbols.

(ix) When a problem is solvable through two schemes of thought, one inferior and the other superior, and if the latter is not well developed, the resort to the former may favour quite a few in solving that problem.

(x) Except occasional fluctuations, the mean performance on the various schemes of thought shows an increasing trend with grade. When mean and standard deviation are kept at 20 and 3 respectively, the gains in terms of T scores over the five-year period are dismal,

implying thereby that they are slow and laborious as they evolve across the grades.

(xi) Using principal component analysis on the combined matrix, containing 45 variables and the varimax rotated factor structures with a view to obtaining the hypothesized factors and interpreting them psychologically, the following multiple factors appeared :

(a) Schematic learning general
(b) Adjustment
(c) Problem Orientation
(d) Sensing Problems
(e) Symbolization
(f) Testing Hypotheses
(g) Using constant Difference
(h) Aspect character
(i) Seeing the problem as a whole.

(xii) The top group differed from the bottom group on all the five measures of adjustment, understanding of the problem and all the seventeen schemes of thoughts. They did not differ significantly from each other in respect of the following variables felt difficulty of the problem, confidence in the problem and interest in the problem.

S.No.	Author	Year	Title of the study	Main Findings
3.	B.S.Bloom & L.J. Broader	1950	Problem solving processes of college students	The successful problem solvers differed from the unsuccessful problem solver in respect of (1) Ability to use of rather than ~~them~~ the possession of the total fund of uninformation. (2) Extent of thought brought forward on a problem. (3) Attitude towards reasoning confidence in the problem and the introduction of extraneous considerations into the problem situations.
4.	R.J.Mealings	1961	Some aspects of Problem Solving in Science	1) Problem solving in Science is more related to intelligence than to chronological age. 2) There appears to be minimum mental age of 13 years before a child can reason formally about a problem. 3) Children should not be expected to solve abstract problem below the mental age of 16+. 4) There is a time long between the empirical solution and formal solution.

S.No.	Author	Year	Title of the Study	Main Findings
5.	N.Vaidya	1964	A study of problem solving in Science. Among certain groups of adolescent children	1) Though adolescent pupils are in a position to state hypotheses most of them are not in a position to test them. 2) They do not, contrary to Piaget, exhaust all possibilities. 3) A given problem is solved over a wide I.Q. range not only within a given age group but also score the various age groups.
6.	S.Jackson	1965	The Growth of Logical Thinking in Normal and Sub-Normal Children.	About half of the 15-year old do attain the formal operational stage.
7.	L.G.Dale	1970	The Growth of Systematic thinking : Replication and Analysis of Piaget's First Chemical Experiment.	Very few adolescents perform at the formal operational level.

S.No.	Author	Year	Title of the Study	Main Findings
8.	A., Newell & H.A. Simon	1972	Human Problem Solving	Logic contributes to information processing psychology through the presentation of ideas by symbols and the consequent alteration in meaningful ways by precisely defined, process symbol manipulation can refer to a much wider range of phenomena than simple-deductive logic. The problem solver can be described and understood as an information processing system.
9.	E.A.Lunzer, C.Harrison & M.Davey	1973	The Four Card Problem and the generality of formal reasoning	Whereas familiarity with the problem influence performance, the incidence of formal operations is quite low in the general population.
10.	S.C.Somerville	1974	The Pendulum Problem Patterns of Performance Defining Developmental stages.	The development of formal thought is strongly dependent on age rather than sex and even the type of school.
11.	R.D. Case	1974	Learnings and Intellectual Development	Even the 7-8 years intelligent and field independent pupils were able to acquite the control of variables in the absence of conservations of weight or combinatorial grouping.

S.No.	Author	Year	Title of the Study	Main Findings
12.	L.A. Graybill	1975	Sex differences in Problem solving ability	Sex differences favouring boys in formal thinking were noticed.
13.	M.C.Linn & D.I.Levine	1976	Adolescent Reasoning the development of the ability to control variables	When the results were stressed and the procedure was hidden from view, the performance of the young adolescent pupils was impaired than the older ones. The gap between the two being as wide as four years. 2) Both groups of subjects performed similarly on the problem when the results were not shown.
14.	M.Shayer & H.Wylman	1978	The Distribution of Piagetian stages of thinking in British middle and sec. school children 14 to 16 years old and sex differentials.	There appears to be a stayput in thinking i.e., beyond the age of 15 years there is no increase in the proportion of pupils showing formal thinkin
15.	T.S.Sandhu	1980	A Factorial Study of Adolescent thought using Piaget type tasks.	Performance on Piaget type tasks increases with age. 2)Boys perform either equal or better than girls on the tasks at respective age levels.

S.No.	Author	Year	Title of the Study	Main Findings
				3) Significant correlation exists between intelligence and the adolescent thought and between academic achievement and adolescent thought. 4) Personality factors play a significant role in development of adolescent thought.
16.	S.C.Jain	1981	A Study of problem solving behaviour in Physics among certain groups of adolescent pupils	Problem solving ability differs significantly among pupils operating at three levels of intellectual development. 2) The performance on problems significantly increased after hints were provided.
17.	M.Mathur	1981	A Study of Growth of Experimental mind during adolescence	Performance on Piaget type tasks shows an increasing trend with grade with quite a bite of fluctuation certain tasks. 2) The capacity of grasp the essence of the problem-ineweasing with grade.

S.No.	Author	Year	Title of the Study	Main Findings
18.	Vandana Raizada	1981	A Study of Relationship between problem solving ability and some relative personality traits using Piagetian tasks	1)Problem solving ability increases with age, grade and intelligence. 2) Sex differences favouring girls exists in Problem solving. 3) Personality traits like persitency. Eregic tension, confirmity, tendermindedness, undemonstrated persecuted and some other correlates which influence problem solving. Whereas others like reserved and detached, assertiveness and aggressiveness, gustfullness do not influences problem solving.
19.	Satya Bahadur Shreshta	1983	The acquisition of problem solving processes during adolescence.	Each problem inhearing a continuous chain of reasoning has its own distinct factorial structure, 2)Processes of thought underlying the problem can be predetermined, 3) These processes of thought across the problem constitute distinct schemes of thought on appropriate grouping.
20.	Manju Jain	1984	A Study of Piagetian logical thinking among certain adolescent groups using.	1)Majority of Adolescent pupils aged 11+ to 14+ are not in a position to reason formally. 2) The mean performance of individual tasks schemes of thought, total adolescent thoughts shows an increasing trend with age.

S.No.	Author	Year	Title of the Study	Main Findings
				3) The mathematical structure of test and tasks showed the existence of following six factors, namely, combinatorial reasoning, grasping sense of the problem, super ego strength, probability reasoning. Classification reasoning and using constant difference
21.	M.S. Padmini	1984	The exclusion of growth variable during adolescent	Adolescent pupils are in a position to state and test hypothesis in all age groups. Both the variable show a increasing trend to age and grade. However the major parts of a thought is characterised by Ergatic behaviour prelogical thought and concweate behaviour. 2) Sex differences in problem solving sometimes favouring boys at other time favouring girls and exists from task to task. However such differences became less marked between girls and boys equally treated at home. 3) The mathematical structure in test and task indicated existance of two significant factors - stating hypotheses and testing hypothesis.

S.No.	Author	Year	Title of the Study	Main Findings
22.	Anand Judith ulz	1984	An investigation into problem solving in physical therapy Education Prerequisites and curriculum solving and motivation	Problem solving skills can be improved through Education. Some negative effects of competition were demonstrated for gifted (high achieving) students.
23.	N.E. Kezekia	1986	Mean performance of thoughts increased	Mean performance on schemes of thoughts increased wise age and grade. Higher mean scores favoured males rather than females children of teachers, doctors, managers and other professionals performed better than others on schemes of thought such as conservation and classification. Childrens of peasants and house wives performed on schemes of thoughts like using constant difference. Combinatorial analysis stating hypothesis, probability and insightful and figural knowledge. The mathematical structure of tasks and tests used in the study showed the existence of factors namely generalised intellectual operations, classifications and generalised logical thought.

S.No.	Author	Year	Title of the Study	Main Findings
24.	Satya Mehndiratta	1987	Combinatorial group	Three groups of pupils classified on achievement differed from each other on all the four processes of combinatorial structure of tests used in this study indicated the existence of three factors: Academic achievement using two beakers at a time interestingly enough, seeing the problem on a whole did not offer as a full fledged distinct factor.
25.	Veena Sharma	1988	Conservation development in Blind Children	Mean perfomance on conservation shows an increasing trend with age. The group of blind fellow follows more or less the same developmental patterns as the group of sighted children. However, a time lag exists significant differenses were noticed in various conservations at different age levels the use of factor analysis showed the existence of the following factors, namely, achievement, conservation of numbers, mathematical ability and language.
26.	Rashna David	1988	A Comparative Study of problem solving behaviour	The incidence of concrete thought favour boys rather than the girls. There is noticed significant relationship between scores on concrete thought and measures of creativity.

S.No.	Author	Year	Title of the Study	Main Findings
				Directed observation or keenness of observation does not appear as a separate factor. The mathematical structure of tasks and tests indicated the existence of 5 factors namely creative thinking the essence of the problem insight and conservation of insight.
27.	V.P. Agarwal	1988	Reasoning patterns in Science among adolescent pupils studying in different type of schools	Majority of adolescent pupils fail to reach the formal operational stage, type of school management does influence the growth of formal though the mathematical structures of tasks or tests used in the study showed the existence of four factors. Organisation versus disorganisation, abstract thought (Piagetian) Academic achievement and Directional diversity.
28.	Avinash Grewal	1989	Hypothesis making and testing ability	Scores on hypothesis making as well as listing abilities were found like significantly correlated wise intelligence. Measures of creativity, school achievement and socio-economic status.

S.No.	Author	Year	Title of the Study	Main Findings
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S.No.	Author	Year	Title of the Study	Main Findings
				Secondly Hypothesise testing ability is not influenced by the type of instructional settings and the grades factor. The mathematical structure of the tasks and tests used in the study showed the existence of five factors. Divergent prediction ability general mental ability, socio-economic factors, hypothetical thinking and developmental factor.

Main Findings :

It is an exciting enterprise to study the functioning of human mind. Why ? It enables us to familiarize ourselves with the sources of knowledge. Their nature, growth and development. If one penetrates a bit deeper, it amounts to studying "man" it self for knowledge enters intemately all human life. So one gets at the developing model of man as it is being built up by psychology. It is in our own interest to know more and more about the "ability to think" for it is bound to pay off in terms of allround adjustment, effective achievement and in general reflecting citizenry. The reported research in the preceeding pages enables us to draw the following tentative conclusions :

1. The human mind is highly dyanamic. It acts on its own and thereby, prosesses quite a bite of spontaneous thought. It would be an exaggeration to add that it is a readily available reservoir of continually developing thought which, in fact is inaxhauslibiles. It on close reflection and under controlled experimentation when understand can be used easily for the development of several diverse concepts underlying the various schools subjects.

2. The concrete operational stage is quite dominent among normal adolescent pupils whereas adolescent pupils are in a position to set up the hypotheses. They are not in a position to test them. At best, they can test one variable at a time in most of the cases. It is safe to conclude that their individual minds in general have not yet become experimental in character.

3. The adolescent pupils are seen to stick to their own ideas. When compelled to think, they do prefer to test their own ideas in the first instance. They commit a large number of errors while solving problems. These errors suffer 'humps' before individual concepts finally settle down in their heads.

4. There appears significant relationships between scores on Piagetian thought and several outside variables such as chronological age, mental age, grade,personality traits, socio-economic status and probably management of the school. Sex differences in a problem solving exist but these need to be studied in relation to the race. Country, region, rural/urban divide and finally, say relegion.

Those, our limited observations are -

(i) There are no significant sex differences in problem solving, if boys and girls are treated equally at home.

(ii) There are no significant sex differences in problem solving, if boys and girls try hard to equalise their performance in the top group.

(iii) There are no significant sex differences in problem solving if boys and girls belong to the backward areas of the districts.

(iv) There is a general tendency among all adolescent pupils to think maximally on Piaget and Piaget type tasks. These tasks definitely fire their imagination. Excluded from purview, of course, are not the blind pupils too.

5. It needs to be stressed that different school subjects demand varying amounts to formal thoughts, mathematically and science demand the maximum. Secondly the role of fast experiences as well as hints and cues is little understood in problem solving. In fact hints and cues only favour those who are at the transitional stage of development, i.e., neares to the mental structure (4)

required for the conopund development. Lastly, it is true that a problem is solved in stages but at the same time it is very difficult to specify its parameters. In other words the concept of stage simply serves a practical end.

6. It is observed that the very language of Piaget as well as of the Piaget type task is deceptives. It is therefore essential to establish equivalence among the various tasks empirically, otherwise it is difficult to recouncil contradictions in various divergent sort of findings. For example problems supposed to be formal may turn out to be concrete one and vice versa to at other times. There is also seen a sufficient time lag between the experimental solution and its formal solution in general terms.

7. It is possible to design tests and tasks scorable on "0" and "1" basis which measures more or less than same thought as measured by Piagetian tasks. In other words psychometric thought is not at right as it is made out to be in literatures. When bench marks or measuring rulers become available the pyramids cannot claim immunity from measurement. However, the length of the ruler can be questioned.

8. It is possible, largely speaking, to predetemine the process of thought underlying a given problem. It is equally possible to classify the processes on the principles of commonality across the problem. Apart from personality traits, our factor analytic studies have shown the existence of the following set of factors, a picture which can be improve these factors are -

(i) Ununiversed factors, general factors, general schematic learning and generalised logical factors. These factors are closely a kin to each other.

(ii) Creative thinking (divergent thinking).

(iii) Piagetian thought (Schemes of thought like conservation, classification and proportion etc. These reflect both concrete as well as abstract thoughts).

(iv) Aptitudes (language, linguistic causal).

(v) Social and causal reasoning.

9. It is further seen that psychometric and developmental studies on intelligence have yet to converge in a single endeavour.

There are a number of cobwebs yet to be removed from the theoritical point of view. It is also equally worthwhile to explore the existence of the fifth stage of mental development. Its existence had been hypothesized by Piaget towards the end of his life. If so, it would take care of aptitude variations and career commitments

on which Piaget and his coworkers have little to say.

10. It is our experience that formal reasoning reflects a general mode of intellectual functioning across experiences and takes contrary to Piagets adolescent pupils and that matter adults too do not become formal reasoners because of age factor above. So it is the best surprising that deficiencies in formal reasoning had to deficiences in school achievement say in mathematics and physics in particular. The development of formal reasoning is related by the both at home and school. Cognitive malnourishment is a wide spread problem for the development of which diverses as well as imaginative measures are very much necessary.

Let us now see how training influences thinking.

11. It is seen that training experiences and practice influence thinking of intelligence is regarded as a mental skill (based upon innate ability). The influence of training is more remarkable if the objectivity of training is highly narrowed down to illustrate.

When scientific principles are approached through experiments, the non verbal aspect of problem solving is influenced positively whereas no influence is noticed in the verbal aspect of intelligence. However, speaking

restrictedly a specific programme of instructing facilitates the acquisition of the corresponding specific concepts and experimental conditions.

12. Training generates ideas and hypotheses. Training influences performance even when a near varient of the old problem is given. Experimental groups, largely speaking showed significant gains in learning over the control groups. Use of thematic material improves performance. Training properly designed and evaluated too is helpful over a wide age range, younger pupils however, do need more of concrete instructions. Specific training aids in the imergence of schemes of thoughts. For example "Exclusion of variable". The traind concept so acquired is seem to be normally spearing minimally general. It would not be out of place to add that direct instruction even a properly planned is not very helpful. In enhancing schemes of thought in other words, generalisation or its transfer effects to the solution of other problems are limited.

13. It is possible to increase inquiry behaviour through reinforcement. Use of formal reasoning in problem solving depends upon chronological age, mental age and grade.

14. Training is more helpful of a pupil become his own teacher gradually. Initially exploratory, invention and discovery lessons go a long way in developing formal reasoning. It may just turn out to be the case that the indredence of puberty may not be a precondition for formal reasoning.

15. It is further suggested that teacher like Piaget should listen more and more to the inaccurate answers of their pupils.

On the basis of the knowledge thus gained thus would be in a position to improve their strategies and tactics of teaching. Secondly it takes time for scheme of thought to develop. In fact these develop from year to year is gradual to slow. However content, context and instructional intentions are some of the factors where difficultely influences learning. Thirdly self learning and pupil to pupil interaction in class may be encouraged and search to made for promising results, if any pupil may thus often up in their own learning. Lastly, pupil use words metamarphically. Our loss of knowledge about where to human rather than go an hammering all the time measures access to the child mind difficult.

Accelerated Learning

Introduction

Why do children go to school ?

What varied professional services do trained teachers provide ? Are schools really performing the job for which they have been established by the state ? Should parents insists on more and more learning on the part of their wards without really understanding what really is at stake ? There is a host of problems here. Our so-called lesson plan in vogue hardly informs us about the way children learn a subject. The so-called principles of teaching hardly clarify anything, for example, simple to complex, concrete to abstract and known to unknown etc. This criticism also applies to the various approaches to learning : trial and error, learning by observation and learning by doing. Even factors like motivation, proper orientation, student's desire for recognition, accomplishment and new experiences and teacher's attitude towards his work do not escape this criticism. The main difficulty with this terminology is that it has acquired psychological status in the very process of rationalisation over the years. Secondly, it fails to provide detailed guidance to the practising teachers in their day-to-day work. Amidst these larger questions, a narrow question worth asking is : How intellectual structures are formed by pupils as they grow ? If some positive answer is available, can these structures be then accelerated ? It is characteristic of our times that as soon as we ask ourselves a question whether we can accelerate that process

or not. No definite answer is available. It is still possible to consolidate the varied view points of well known psychologists.

(a) L. S. Vygotsky's View -

Jean Piaget leaves us wondering about the educational implication of his work. Vygotsky goes a step. Further by saying some what as following : "instruction precedes development". He, therefore, analyses intellectual development as a function of instruction explicity. For him, concepts do not exist in isolation like 'peas in a bag'. Concepts are measures of generality which interact with each other. Each concept throws light on lower concepts. For example, algebric concepts throw light on arithmetical concepts. Further, he distinguishes between two types of concepts, namely, every day concepts (spontaneous) and scientific concepts. They develop in opposite directions but it is the instruction which is the main source of child's ideas. It corrects, informs and develops his knowledge. Instruction is not something external but is seen to be integrated closely with development. So, planned instruction can accelerate mental development or cognitive function. We should aim at the ripening of such functions. The views of Piaget and Vygotsky along with the concept of productive thought thrown in from the Gestalt psyshology, it appears, present an integrated viewpoint to the teachers for teaching several school subjects.

(b) Z.P. Dienes's View -

His work is on the concepts of abstraction and generalisation but with this limitation, he has studied the attainment of specific mathematical concepts in depth. In his work, he distinguishes between the constructive thinker and analytic thinker. The former takes on overall view of the goal, works intutively towards it, does not concern himself with the details in the beginning but may attend to them later on. Such children, according to him, manifest constructive thought and are at the concrete stage of mental development. On the other hand, the analytic thinker progresses towards the vague goal initially and consciously, step by step. Children at the formal stage of development exhibit analytic thinking. The emergence of the analytic thought becomes highly probable when constructive thought has already been well developed. There may be certain cases when poor constructive thinkers may manifest analytic thinking. In that case, one can be pretty sure that they manifested 'Shadow actions' without any logical sequence of various events. He then emphasises that the majority of children need a lot of constructive activities before we can expect them to develop analytic understanding. He has investigated and illustrated his ideas with the help of his specially constructed multibase arithmatic base and algebraic experiences material. He has then formulated four principles of conceptual learning. Which are :

1) The Dynamic principle
2) The perceptual variability principle
3) The mathematical variability principle
4) The constructivity principle.

Our gain will be immense if we classify the whole science syllabus (equally true to some other school subjects) at these four levels in the form of learning situations to be gradually presented to the youngesters at various age levels. Accelerated scientific and mathematical thinking may then result.

(c) It is said that advances in knowledge take place only when assumptions underlying thought processes are questioned. Bereiter and Engelmann, while working at the Institute for Research on Exceptional children at the university of Illinois, in Urbana, operated, a sort of intellectual pressure cooker in quite an unconventional way. They, in the process, rejected much of progressism in the play oriented nursery school. Instead, they concentrated forcefully on limited skills of teaching for about two hours a day. Let us illustrate their approach in a mathematics lesson with four pupils.

> It is time to think about ... ... work, he began fairly shouting. Are you ready for tough stuff ? On the black board, he writes 8 + 3 = ?

> Immediately, the children started roaring 'Eight plus zero equals eight. Eight plus one equals nine, eight plus three equals eleven and the sums like 5 + 9 = 13 and 7 - 5 = 2. It look like algebra for four year olds.

It does not take much time for them to extract meanings from statements. They are in a position to talk in simple sentences. They also get experiences of success as they go along with their work. Teachers have faith and confidence in their children and vice versa. It is interesting to note that those games result in the very process of work with deep involvement and commitment to a common task.

(d) It is necessary to distinguish among logical structures of a subject; its underlying processes of techniques and their psychological mode of presentation. It is possible for the child to acquire knowledge at an early age when it is of immediate interest and value to him. According to W.D. Wale, two situations may have different underlying psychological processes even when their content remains the same. Hyram pointed out that school work improved when pupils were trained on logical operations. Similar was the experience of Morf when he tried to induce class inclusion, using direct training on the operations of logical multiplications. These results, however, did not receive support from the studies of Lovell and Ogilive, and Dowedell. Interestingly, D. Elkind found that 53 per cent

of the American pupils in the age group of 12-18 years failed to conserve volume. Hence, there is a scope for improvement here to acquire this scheme of thought unaided. Here, there may underlie problems which may be philosophical, psychological and technical.

(e) Marcia C. Linn & Herbert D. They investigated the effect of experimental Science on development of logical thinking in children. They set up experimental and control groups. With a view to obtain evidence whether SCIS project really contributes to cognitive growth. The unit for treatment with experimental group was that of energy, one which illustrated interaction. The role of teachers who were on the SCIS project is different. It is to stimulate the cognitive growth of children which implies that the teacher is not in the class room to tell children what Science is ? On the other hand, she is there to help them to find out what Science may be. She has to create an environment that invites and supports curiosity, modes of investigation and inquiry. They designed a group test presented on a 16 mm. film called the cost experiment which went down the ramp from either position. It moved on a blue or brown surface, hit the wall and come finally to rest after bouncing repeatedly. The experiment was carried out on the fifth graders.

The control groups come from fifth grade and eighth grade. The main findings of this project indicated:

i) The unit taught did succeed in advancing logical thoughts. The fifth graders of the experimental group showed gains in scores in comparison to the central group of fifth graders. Nay their scores were very close to the control group of eight graders.

ii) The gains in scores were due to the fact that students act on things, use materials, name variable, and carry out discussions among themselves. Use of language and skills in logical thinking are the other factors which could be taken care of while working with fifth graders.

iii) There existed large individual differences in scores on the cart experiment both for the fifth and eight graders. But interestingly enough percentage of formal reasoners in both the groups was more or less the same. Then they state that educational programmes while accelerate cognitive growth do require some sort of mechanisms to tackle the problem of individual differences.

(f) Teacher is not merely a spectator and observer of class-room events or merely facilitator. He is expected to plan his teaching schedule with certain objectives in mind. He has to find varied ways and means to achieve

these objectives. He should begin where the children of his class are rather than where he is. He is free to decentralize his methods of teaching even to the point of extinction. Individual and group work can be so arranged where individual children are free to judge the relevance of what they are talking, discussing and evaluating. Research on training studies has suggested certain strategies for accelerating thinking. According to D. Kuhn (1974) such studies centre on :

1. Training attention. These children should be trained to ignore the irrelevant features of the problematic situations, for example, factors of length, height and width in conservation experiments. Why ? The length of one of the two equal match-sticks does not increase when it is moved side ways either way.

2. Providing information : Relevant information should be provided to the children about the results of determining and transforming of the experimental materials. Feed-back may be given in the form of right or wrong after children have given their judgements.

3. Verbal rules : They can be provided with rules for solving a given series of problems. The amount of liquid in both cases remains the same because nothing has been added and subtracted in the experiment.

4. Cognitive operations : There can be direct training on several cognitive operations, For example, reversibility, compensation, combinational grouping and so on.

5. Cognitive conflict : Cognitive conflicts are induced in the experimental situations. Children are allowed to predict and, later on, test their judgement concretely before their very eyes. Vaidya (1979) set up several problematic situations where he intentionally invited subjects to given wrong answers. Under controlled conditions, he predicted the existence of "hump effect". According to him, their errors must suffer humps before concepts get firmly established in their heads.

It is not easy to pinpoint genuine structural changes. Brainerd and Allen carried out a training density experiment involving density, solid volume and liquid volume. Ten to eleven year children were exposed to the density conservation traits. The experimental group received feedback. The control group, however, answered the same experimental materials. The results of this study indicated that feedback was an effective technique for density conservation. The generalised transfer was an effective technique for density conservation. The generalised transfer was limited to solid volume rather than the liquid volume conservation. In sum, we can say that training is helpful in inducing development. But are

the paths to development in both the cases. The same is not known ? So, is the case with the lasting value of the induced development. Or, should we repeat the experiment by changing the setting of the experiment.

(g) In an interesting study, Updesh K. Bevli (1982) investigated the concept of speed as well as influence of training on the development of this concept among certain groups of children (both boys & girls) studying in different types of schools. The result of this study indicated that even by the age of 12 plus, 28 per cent of urban advantaged group and 79 per cent of the rural dis-advantaged group are not in a position to develop the concept of speed. Secondly, the concept of speed hardly appears below the age of six years. Thirdly, within the Piagetian context, the influence of training has not proved in the upgradation of responsees. Fourthly, the type of school, socio-economic status and training in the concept of time do favour the concept of speed. Then comes her tolling comment when she says -

> An ordinary school is not sufficient to ensure a normal development of operational structures. It seems to be the result of the sum total of the environment consisting of the school, the home and the level of the technical development of society itself.

(h) Based upon her Doctoral work, Padmini T. (1983) has something substantial to say on fostering cognitive development at primary school with entrants ranging in the age group of five to seven years. Using the Soloman group design technique, she tried her experimentally designed programme comprising concepts and operations within the Piagetian framework on 120 pupils spread over five different schools in equal numbers. Two experimental and two controlled groups were set up for determining the efficiency of the programme over a period of 40 sessions; and each session lasted about 30 to 40 minutes. Boys and girls were also taken in equal number. Concepts to be developed related to length, area, weight quantity, spatial relations, temporal relations and feelings of belongingness. The operations, on the other hand, comprised identification, generalisation, comparison, identification, generalisation, comparison, discrimination, seriation, classification, reversal, compensation and cause and effect reasoning. Cognitive development was measured by the Mysore cognitive capabilities tests. Other outside variables included in her study were age, socio-economic status, type of school, academic achievement and the incidence of pre-school education activity. Whereas her experimental programme favoured the experimental group more than the controlled group, it turned out to be a sort of culture fair rather than culture free programme, From which children of all sorts could draw equal benefit from well-designed cognitive activities. Other findings were

plausible. She then had the following telling comment to make :

> But the accomplishment of the 20-24 hours in 40 sessions special activity programme spread over six months and forming a thin column of enrichment resulted in more than doubling this improvement as seen in the gains of experimental group which would shatter that satisfying picture and highlight the distortions in purpose, displacement of focus, shallowness of efforts and resultant failures and wastage rather than achievements and successes. There is no gain saying the fact that the ordinary school curriculum as implemented in the best of our school does not facilitate maximum cognitive growth".

(i) Anu Poonia (1988), after reviewing the literature on training studies, attempted to determine the influence of training on adolescents under controlled experimentation with the help of a specially designed test. She classified pupils at 3 levels of intellectual development, namely, concrete, transitory and formal. The study sample comprised 320 pupils, both boys and girls studying in grades 7 to 10. These study sub samples were further matched on intelligence, grade and socio-economic status. They were met in three training sessions, There was quite a bit of variety in the training materials . The main results of her study were :

a) Pupils at all grades do not draw equal benefit from training. In other words, training is helpful under certain conditions only.

b) Training is helpful to those who are at the transitory stage of mental development, that is, between the concrete stage and the formal stage.

c) Significant differences were not noticed, as judged by the means test, between the control group and experimental group at three different levels of intellectual development, sex-wise as well as grade-wise. In other words, the Piagetian scheme of though is not easily influenced by training instantly under experimental modes of presentation rather than oral, pictorial and demonstration modes of presentation, each taken individually.

(j) Philip Adney and Michael Shayer (1990), both experts of long standing in Piagetian Psychology, have investigated the acceleration of the development of formal thinking in middle and high scholl students in a country wide project called Cognitive Acceleration through Science Education (CASE). In a way, there is nothing new about such studies. For example, Sieglar, Libert and Liebaert (1973) found that even 10 year old pupils could be trained to solve the well known simple pendulum problem. They could thus form and test hypothesis. It was a case of direct training on the problem with no attempt to test for generalisation to other contents and schemes of thought. Let it be understood that such givens are superficial. Even a young child

could be trained to switch on or off the television set with the help of remote control device. The real problem for him only arises when either the main switch of the house is off or there is no current supply available at that moment. In other words, it means that what is important is the play of variables either singly or otherwise underlying a given situation. Such a line of attack has been adapted in their studies where pupils are introduced to the motive of measurement as well as dimensions. Attaining the specific solution of the problem is of secondary importance. Let us now return to the CASE project.

The project was carried out in day to day settings of the school itself. Control groups were also set up to measure gains in interventions made which were as many as 30 in number. The project staff and teachers produced intervention lessons in physics, chemistry and biology which were based upon formal operational thought. It was kept in mind that not more than 25 per cent of the usual time meant for Science teaching will be given to the experimental classes. This in a way kept in fact the school routine. There was however another spin off advantage of this project. The project teachers could become more sensitive to the sources of pupil difficulties in varied learnings and, thereby, develop certain strategies for the benefit of their pupils. The schools for this study were drawn from seven different areas in England. For

example, inner city, urban and rural schools. All the schools were co-educational. Age range covered was from 9 years to 18 years.

Let us now refer to the interventions. The intervention lessons, each of 60 minutes to 80 minutes duration incorporated formal operational schemes of thought such as exclusion of variables, ratio and proportion, equilibrium, compensation, combinatorial thinking (grouping), correlations, probability and conservation involving formal modelling. Initially each intervention lesson focussed on one scheme of thought. As the project progressed, the pupils were familiarized or led to see for themselves the meaning of the variables. Value of variables and the relation among them. It should not be lost sight of that pupils were given such problems which require the use of formal reasoning. In these situations, there were no attempt to teach the rules of the game. Instead the pupil is expected to construct and use his own scheme of thought for solving the practical problem. This, in a way, is the beauty of the project. However, the findings of this project are not clear-cut. The experimental group gained more in levels of cognitive development. Statistically speaking, than the control group. More specifically, it amounted to 2-3 months differential in development nor a period of 2 years. It means in other words that this much extra-effort is not worth it. The same is the case with enhanced achievement in Science, a case of more or less dismal failure. The age/gender

interaction as seen from the data is also found to be puzzling. At the same time evidence suggests that the intervention for the development of accelerated thinking favours boys in the age group of 11 to 13 years and girls of the age group 12 years to 14 years.

Lastly, the Piagetian schemes of thought are not easily anenable to influence "Nature first creates the material before it gives it a form", Echaed J.J. Rousseau in the 17th century : It is true that the current teaching routines do not alter the rate of intellectual development. But a gain of 23 percentile points obtained in 20 months in the case of experimental classes suggests that the number of pupils showing in traditional school sciences and mathematics. To put in other words it ought to be the main objective of school to "alter cognitive development rather than to adapt instruction to existing norms". However, for achieving substantial gains in cognitive growth. A long term project as part of inservice education is urgently required.

Some studies related to the accelerated learning are as follows :

A survey of research
on
training of studies

Let us now refer to some research studies on training. No clear cut finding is possible

because the various findings of such studies are either positive, negative, neutral or doubtful influences. These studies are now presented in the tabular form below:-

1) Training Studies Showing Positive Influence

Sl.No.	Name of Author	Year	Title of the Studies
1.	S.C. Mumford	1937	Factors involved in problem solving with special references to the problem of Insight.
2.	S.H. Bank	1958	How pupil in a secondary modern schools induce scientific principles from science experiment.
3.	J.R. Devane & H.J.A. Rimoldi	1961	Training in problem solving.
4.	F.H.Mc. Donald, and W. Shockley	1964	Teaching scientific thinking at High school level.
5.	E.A.Lunzer and Coombes	1969	Teaching for formal reasoning.

Sl.No.	Author	Year	Title of the Study
6.	N.M. Simcox	1970	Improvement in the logic of 8 year old children.
7.	C.J. Barainerd and T.W. Allen	1971	Training and generalization of density conservation etc.
8.	R.J. Shavelson	1971	Some aspects of the relationship between content structure and cognitive structure in physics instruction.
9.	P.C. Wason & D. Shaprio	1971	Natural and contrived experience in a reasoning problem.
10.	J.Bass and E. Montague	1972	Piaget Based sequence of instruction in science.
11.	M.E. Quinn	1972	Hypothesis formation of Instruction in science.
12.	K.C. Tomlinson	1972	Formal operations in females from eleven to fifty four years of age.
13.	V.K. Wiegand	1972	A study of subordinate skills in science problem solving.

Sl.No.	Author	Year	Title of the Study
14.	R. Case and C. Fry	1973	Evaluation of an attempt to teach scientific Inquiry and criticism in a working class High school.
15.	R.L. Kimball	1973	The teaching and understanding of formal operations.
16.	J.W. Renner & A.E. Lawson	1973	Promoting Intellectual development through science teaching.
17.	R.S. Siegler D.E. Liebart & R.M.Liebart	1973	Inhelder and Piaget's Pendulum to Act as Scientist.
18.	V.M. Talisayan	1973	Some cognitive variables in meaningful learning of the physics, concepts of work and enegy.
19.	W.B. Qoeslin	1974	An analysis of content structure and cognitive, structure in the control of a probability unit.

Author	Year	Title of the Study
B. Inhelder H. Sinclair & M. Bovet	1974	Verbal Training Procedure of conservation of continuous quantities
A.E. Lawson, G.H. Norland & A. Devito	1974	Piagetian formal operational tasks. A cross over study of learning effect and reliability.
M.D. Berzonsky T.P. Lambardo & M.A. Ordranko	1975	Changes in logical thinking as a function of induced disequilibrium
A.E. Lawson, A.J.D. Blake & F.H. Norland	1975	Training effects and generalisation of the ability to control variables in High school Biology students.
M.C. Linn & H.D. Thier	1975	The effect of experimental science on the development of logical thinking in children.
R.S. Seigler & R.M. Libert	1975	Acquisition of formal scientific reasoning by ten and thirteen year olds. Redesigning and factorial experiment.

S.No.	Author	Year	Title of the Study
26.	D. Kuhn and J. Angelev	1976	An experimental study of the formal operational thought.
27.	J.W. Renner	1976	Scientific physics content and intellectual development. cognitive development as a result of Interacting with physics content.
28.	A.E. Howe & J. Mierzwa	1977	Promoting the development of logical thinking in the classroom.
29.	M.C. Linn B. Chen & H.D. Thier	1977	Teaching children to control variables.
30.	K.D. Peterson	1977	An experimental evaluation of Science Inquiry Training Programme for High School students.
31.	J.J. Rastomae	1977	The effect of Instructional mode on school achievement of concrete and formal operational students.

S.No.	Author	Year	Title of the Study
32.	W. Wollman & A.E. Lawson	1977	Teaching the procedure of controlled experimentation - a Piagetian approach.
33.	M.C.Linn & D.I. Levine	1978	Adolescent Reasoning : Influence of Question formal and type of variables on ability to control variables.
34.	T. Warrent, W. Wollman & A.E. Lawson	1978	The influence of instruction on proportional reasoning in seventh grades.
35.	E.L. Wright	1978	The effect of film mediated Intensive instruction on basic problem solving skills of Ninth graders.
36.	D.L. Schallert & G.M. Kleiman	1979	Teacher easier to understand than the textbook.
37.	R.Rosenthal	1979	Pygmation effects : Existence, magnitude and social importance.
38.	Edwards, H. Clifford & M. Surma	1980	The relationship between type of teacher reinforcement and student inquiry behaviour in science.

Author	Year	Title of the Study
G.S. Bawa	1981	The effect of training and intelligence on formal operational thought (stating and testing hypotheses).
A.E. Lawson & D. A Snitgen	1982	Teaching formal reasoning in a college biology course for pre-service teachers.
E.D. Riesz	1981	The effect of training on children's classification skills.
V.K. Bevli	1982	Concept formation in children in eco-cultural context.
C.I. Sneider	1982	Can children learn How to control variables - a Neo Piagetian training study in school and non-school setting.
L.H. Compbell	1983	The effect of cognitive strategy training on reading achievement Piagetian cognitive level among high risk college freshmen.
M.R.Mandar Avalli	1990	Cognitive development in blind children.

2) Training Studies Showing Negative Influence

Sl.No.	Author	Year	Title of the Study
46.	C.S. Arfin	1976	A comparison of the effectiveness of direct contact with children in the classroom versus indirect contact via-video tape in Piagetian conservation tasks in preservice teachers.
47.	M.C. Linn, B. Chen & H.D. Thier	1976	Teaching children to control variables investigation of a free choice environment.
48.	C.A. Stone & C.M. Day	1978	Levels of Availability of a formal operational strategy.
49.	M. Wyatt	1983	Formal operational thinking and the role of training.

3) Training Studies

Showing Neutral Influence

S.No.	Author	Year	Title of the Study
50.	G.F.Bradley	1972	Reinforcement and Reversability in Quantity conservation acquisition.
51.	H.J.A. Rimoldi & et.al	1962	Training in problem solving.
52.	D. Nasca	1966	Effect of varied presentations of laboratory exercise within programmed materials on specific intellectual factors of science problem solving behaviour.
53.	O.E. Dyrli	1967	An investigation into the development of combinatorial mechanism characteristics of formal reasoning through experimental problem situations with sixth grade students.

Author	Year	Title of the Study
J.K. Davis	1967	Concept identification as a function of cognitive style procedures.
Et al Ennis	1969	Conditional logic and children
R.R. Buell, & C.H. Brainerd	1972	Piagetian studies in science chemical equillibrium under standing from study of solubility.
T.A. Bredderman	1973	The effect of training on the development of the ability to control variables.
C.J. Brainerd	1974	Training and transfer of transitivity conservation and class inclusion length.
R. Case	1974	Structures and strictures: Some functional limitations on the course of cognitive growth.

S.No.	Author	Year	Title of the Study
60.	A.E.Lawson, A.J.D.Blake & F.H. Horland	1975	Training effects and generalisation of the ability to control variables in high school biology students.
61.	M.C. Linn & D.I. Levine	1976	Adolescent Reasoning : The development of the ability to control variables.
62.	A.E. Wheeler & H. Kass	1977	Proportional Reasoning in introductory high school chemistry.

4) Training Studies Showing Doubtful Influence

S.No.	Author	Year	Title of the Study
63.	F.D. Baulanger	1978	Interaction of formal operational capability and instructional feedback mode.

S.No.	Author	Year	Title of the Study
64.	F.G. Gunnels	1967	A study of the development in logical judgement in Science of successful and unsuccessful problems solvers in graders four through nine.
65.	R.J. Raven	1974	Programming Piaget's logical operations for science inquiry and concept attainment.
66.	S. Strauss & I. Rimall	1974	Effect of organisational disequilibrium elaboration.
67.	E. Silver	1976	Relations among Piagetian grouping structures - a training study.
68.	C.B. Dauglass & J.B. Kahle	1978	The effect of instructional sequence and cognitive style on the achievement of high school biology students.

Concluding Statement :

We respect nature because it has orderly ways of doing things. If something goes wrong or nature becomes errectic, we are defiitely in a position to apply appropriate remedies, both theory based and empirical in nature. In other words, these appropriate remedies are our intervention programmes which can yield intellectual gains for all sorts of pupils who are, for example, gifted, normal, sub-normal and the children of the poor. The basic problem to be answered is - what is the lasting value of all such initial advantages ? Are these gains maintained in the succeding grades too ? In our opinion, these initial gains should get wiped off beyond the mid-concrete stage of mental development. Not only our answers but also questions raised within the context of intellectual growth and development are not yet very clear for cognitive growth may take place from outside as well as inside. Despite these difficulties, it is possible to draw some lessons from research done so far on accelerated learning is concerned. These are as follows :-

(i) Experience in one form or another is necessary for intellectual development.

(ii) Pupils operating intellectually below their optimum level of development as well as at the transitory stage of mental development within the major beneficiaries of the intervention programmes.

(iii) There are wide limits within which the training materials can be structured and made more relevant, thought-provoking and interesting.

(iv) It is necessary to keep alive the concept of centring, decentring, recentring and so on in our day to day teaching. It is only in this way that knowledge is continuously constructed and reconstructed. It is, therefore, essential to familiarize our teachers with the following techniques :

a) Training in observation and attention
b) Solving problems by using minimum essential information including hints.
c) Stress on cognitive operation and conflicts and deductive teaching; and lastly
d) The use of chain inquiries in making the teaching-learning process more interesting, more effective and more productive than is the case today.

(v) Accelerated learning is not a case of single shot at all. Pupils need to be introduced to such strategies over a longer period of time. Their mental tools need to be developed gradually so that they can sense the basic essentials underlying the problem and do something about it. Philip A. dey and Michal Shyre have aptly remarked :

> We hypothesize that it is the process of constructing their own meanings which leads students to the cognitive restructuring responsible for increased scores of experimental groups.

Nay, one has to go further. Teacher's need to be trained to have a look at what they teach from the Piagetian point of view. They will then have vague idea of structure in their teaching learning process. Once done, the transition to the zone of proximal development (L.S. Vygotsky), Learning by discovery (J.S. Bruner) and advance organizers (David Ausubel) is not far a way.

The Study

The Study

troduction

The Piagetian child is active by nature. Thinking mes as naturally to him as walking. He has explained s view about the growth of thinking right from early ildhood to late adolescence within the context of netic epistemology. Thus, it is inherent in the ture of this model that it cannot be falsified. He us sets himself apart from Karl Poffer who advocates e falsification rather than affirmation of a ypothesis in testing the truth of an idea. In the resent study, the main objective is to accelerate upil's thinking process in two ways:

i) By exposing them to a set of experiences called the equalizing experiences. Here, the problems posed must be answered by the group of pupils in a reasonably satisfactory manner. Assistance is provided on each problem until it is fully solved. In other words, it ensures the understanding of the problem which is not scored.

(ii) In the second part of the study, a few Piaget and Piaget type tasks are presented individually to 33 pupils individually with a view to check whether these pupils show, at least, induced

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form of formal reasoning. There were no time limits for either part of the study.

Being an exploratary study which was just to understand this complex phenomenon, it was decided to examine the responses, using the Guttman scale for judging the unidimensionality of the thought process. Here the coefficient of fluctuation was calculated by using the following formulae:

Percentage of coefficient of fluctuation =

$$\frac{\text{Number of errors}}{\text{Total responses}} \times 100 = i$$

Which enables us to determine the coefficient of reproducibility = 100 - (i)

The coefficient of fluctuation in percentage should not be more than 20. Ideally, it should be less than 10 per cent.

It also became possible to report additional data fom other major studies by:

(i) Vaidya : A study of problem solving behaviour.

(ii) Vaidya and Padmini: The exclusion of variables during adolescence.

(iii) Vaidya and Satya Mehndiratta: A study of combinatorial grouping.

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(iv) Vaidya and Annu Poonia : The effect of training on controlled experimentation.

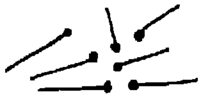
These studies provide a broad base for developing assault courses on accelerated thinking and problem solving in the near future.

The Scheme of Equalising experience

The equalizing experiences are the tasks on which we expect most of the students to perform well. Some of the equalizing experiences are given below:

(i) Matchstick problem

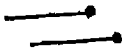
Here are a few match sticks.



Out of these pick up any two matchsticks which you feel are of equal length.

(The student picks up the two sticks. Now the following questions are put to him)

Now which of the two matchsticks is longer?



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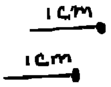
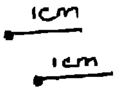
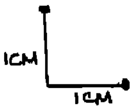
Which of the two matchsticks is longer now ?

If a child is unable to understand the problem care is taken that he can understand that the two sticks are of the same length by telling him the length of both the sticks.

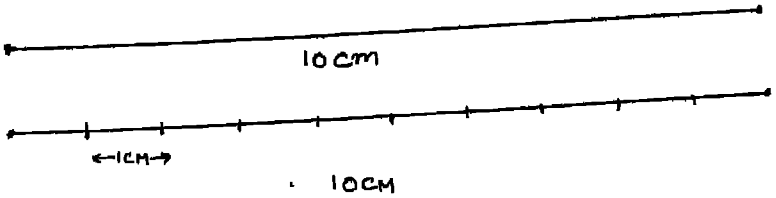






(ii) Cutting of the stick problem

We have here a stick of 10 cms length. If we decide to cut this stick by 1 cm per day, how many days will it take to cut the whole stick ?



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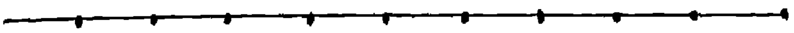
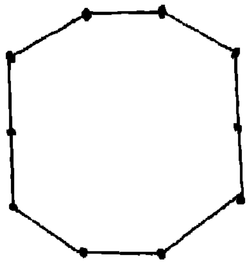
This problem can also be explained in a different manner. 10 matchsticks are placed together in a line to form one stick as shown below:

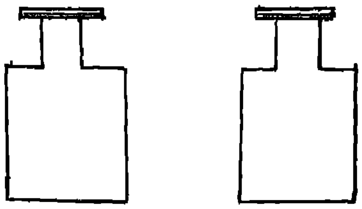


These sticks can also be presented to the child in the following manner:

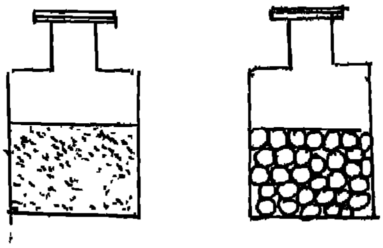


(iii) Conservation of volume

I have with me here two identical glass jars



In one jar I put some sand and in the second jar I have put some metal balls.



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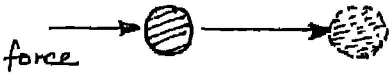
Now if I put these glass jars one at a time in a tumbler full of water, which of the two glass jars is likely to displace a greater amount of water.

(iv) Rolling the ball:

I have a ball with me. I will now roll it on the floor:



You can see that the ball stops after some time. Why does the ball stop ?

If I want that the ball should move a greater distance what should I do ?

(v) Handkerchief problem:

(i) Length of handkerchief.

(ii) Thickness of handkerchief.

(iii)Nature of material.

Your task is to suggest experiments which will isolate these factors:

(i) Length of handkerchief.

(ii) Thickness of handkerchief.

(iii) Nature of material.

Piaget and Piaget type problems used for judging the acceleration of thought

The following problems were used in the second part of the study.

(a) Combinatorial grouping

- (i) Dance problem
- (ii) Digit problem
- (iii) Beaker problem

(b) The Exclusion of Variables.

- (i) The simple pendulum problem.

The first problem relates to the operational schemata and the second problem to the propositional

logic. Both the underlying schemes are, of course, related to each other but appear at different ages.

The effort of our experiment is now described in the next chapter, under the heading:

(i) Teaching for combinatorial grouping.

(ii) Teaching for exclusion of variables.

The experimental study

1. How to teach for combinatorial groupings ?
2. How to teach for exclusion of variables ? (Controlled experimentation)

1. How to teach for combinatorial groupings ?

Introduction

The studies on thinking of adolescent pupils were conspicuous by their absence as late as 1958. Piaget and Inhelder commented on the scarcity of such studies as follows:

> It is surprising that inspite of the large number of excellent works which have been published on the affective and social life of the adolescent - we hardly need remind the reader of the studies of Stanley, Hall, Compayre, Mendousse, Spranger, Charlotte Buhler, Landis, Wayne, Dennis, Brokks, Fleming, or Debesse, or those by psycho-analysts such as Anna Freud and Helene Deutsche, and by sociologists and anthropologists such as Malinowski and Margaret Mead, not to mention others - so little work has appeared on the adolescent's thinking. (page 334).

So there is no coherent outline available. At best, the conventional tests of intelligence inform us about the hypothetico-deductive nature of formal thought. It is then the Genevans who set the ball rolling. Since then there have been spate of such studies in the entire English speaking world. In "The Growth of Logical Thinking", Piaget and Inhelder listed fifteen problems which relate to developmental aspect of propositional logic and operational schemata of formal logic. The two problems selected for investigation in this study for developing acceleration of thought are:

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(1) Combinatorial grouping i.e. combinations of coloured and colourless chemical bodies or the beaker problem (Operational schemata of formal logic)

(2) The oscillation of a pendulum and the operations of exclusion (The simple pendulum problem based upon formal logic)

The Piagetian problem

The combinatorial grouping refers to a scheme of thought (operational scheme) which appears on the onset of formal reasoning. It equally applies to the formation of propositional logic which, in turn, implies the existence (establishment) of a combinational system. In other words, identifying and controlling experimental variables are underlying the combinational system. Before the emergence of formal reasoning , these combinations are haphazard or more or less random. Later on, the attack on the problem is systematic implying thereby that the adolescent pupil adopts a step by step combination made with generalization. In summary, the "structured whole" as visualized by Piaget depends on this "combinatorial system which is manifested in the subjects' potential ability to link a set of base associations or correspondences with each other in all possible ways so as to draw from them the

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the relationship of implications, disjunction, exclusion" etc. The problem as presented by Piaget is now reproduced below:

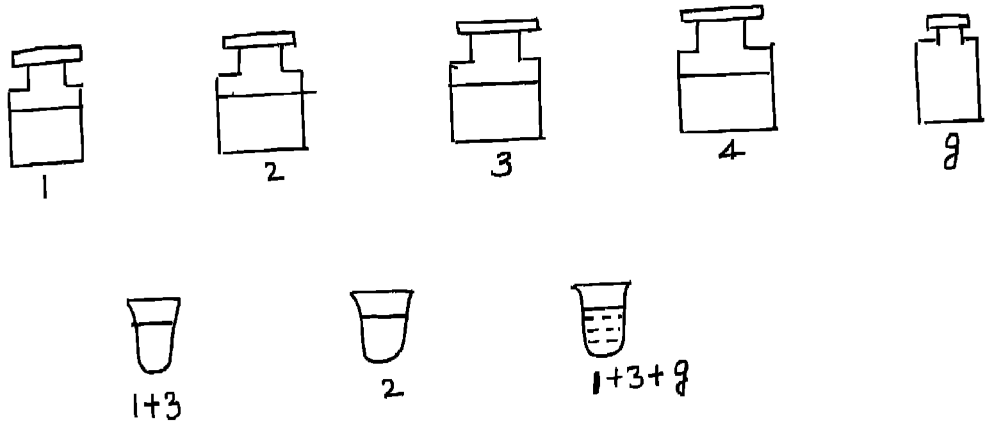

Fig. 1

It illustrates the problem of coloured and colourless chemicals. Four similar flasks contain colourless, odorless liquids; (1) dilute sulphuric acid (2) water (3) oxygenated water (4) Thiosulphate. The smaller flast labelled 'g' contains pottasium iodide. Two glasses are presented to the subject; one contains 1+3, the other cotains 2. While the subject watches, the experimenter adds several drops of 'g' to each of these glasses. The liquid in the glass containing 1+3 turns yellow. The subject is then asked to reproduce the colour, using all or any of the 5 flasks as he wishes.

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The growth of solution

Let us see the growth of the solution over a wide age-range extending from 6 years 6 months to 14 years.

E.G. (6.6): (Ind x B) "It turned Pink. May be there is paint in the glass (Ind x AC). May be the piece melted. May be the paint flatttened out completely in the glass. (Ind x B) Rose. May be its because the water changes. May be it changes at the surface of the water. (Acxind XE) . May be its because when you have taken some while water in the tube, there is a bare that stops it and its the pink water that runs out."

Ben (7:1) tries 4 x G, then 2 x G, 1 xG; "I think I did everything ....I tried them all" - What else could you have done ? " - "I don't know.". We gave him the glases again; he repeats 1xg, etc.- " you took each bottle seperately. What else could you have done ?" - Take two bottles at the same time " (He tries 1x4xg then 2x3xg, thus failing to cross over between the two sets (of bottles) for examples 1x2, 1x3, 2x4 and 3x4) - when we suggest that he add others, he puts 1xg in the glass already containing 2x3 which results in the appearance of the colour. "Try to make the colour again ", Do I put in 2 or three ? (He tries with 2x4xg then adds three, then tries it with 1x4x2xg). No, I don't remember any more etc.

CUR (8,11) also proceeds one by one with g: Nothing happens . You can't do it unless you put everything in the same glass." He mixes the four without success, then hypothesizes not that he has put in too uch but that he should have chosen another ordr; "Nothing happens. I should have started with that one. he does this but since he does not control

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the permutation operations any better than the combination operations he follows the sequence 2, 3, 4, 1, g, then he adopts any sequence whatsoever: " The colour does'nt come because I did it in several." Finally (always with the intention of blending the four) he follows the sequence 1x2x3xg: "It's becoming yellow" But immediately he adds four and has to begin all over again. "Put in as few as possible - The fewest possible, that's "two.

KIS (9;6) begins with (3xg) + (1xg) +(2xg)+(4xg), after which he spontaneously mixes the contents of the four glasses in antoher glass; butthere are no further results. "O.K., we start over again." This time he mixez 4xg first, then 1xg; "No result." Then he adds 2 x g, looks and finally puts in 3xg. "Another try (1xg, then 2xg, then 3xg). Ah! (yellow appeared, but he adds 4 x g). Oh ! so that! (4) what takes away the colour. 3 gives the best color." -- "Can you make the color with fewer bottles ?" - "No". -- "Try" (he undertakes several 2 by 2)combinations, but at random.

ALB (10;4) begins with 1 x 2 x 3 x 4 x g, then changes the order 3 x 2 x 4 x 2 x g. " It's different, because the first time I went in order and this time I didn't. (he puts 2 x 4 x 1 x 3 x g.) Gives nothing" (he tries several more permutations at random, then abandons the effort). -- "do, you have to take all of them ?" -- :"No, you can take 2 or 3 if you want (he tries unsystematically and succeeds bychange). It changes !"

TUR(11;6) begins with 1xg, etc. "That does'nt work. You have to mix all four (he does this). That doesn't work either (he changes the order several times without success, then tries two-by-two combinations: 1 x 4 x g, 2 x 3 x g, 3 x 4 x g). I wonder if there isn't water in all of them !" Then he spontaneously moves on to three-by-three combinations

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(x g), but without order: 3 x 4 x 1 x g, then 2 x 3 x 4 x g, then 1 x 4 x 2 x g, then 3 x 1 x 2 x g. "That's it." -- "What do you have to do for the colour ?" -- "Put in 2. " -- "all three are necessary ?"-- One at a time (always with g) it doesn't work. It seems to me that with two it doesn't work; a liquid is missing." -- "Are you sure that you have tried everything with two ?" -- "Not sure (he tries in addition 2 x 1 x g, already attempted, then 3 x 1 x g). It works ! It's 1 and 3 !" -- "Tell me what effect the bottles have." -- " 1 is a colorant, 2 prevents the color; no it doesn't prevent it because it worked, 3 takes away the effect of 2, and 4 doesn't do anything".:

ENG (14;6) begins with 2 x g; 1 x g; 3 x g; and 4 x g : "No, it doesn't turn yellow. So you have to mix them." He goes on to the six two-by-two combinations and at last hits 1 x 3 x g: "This time I thik it works." -- "Why?" -- "It's 1 and 3 and some water." "You think it's water ?" -- "Yes, no difference in odor. I think that it's water." -- "Can you show me ?" -- He replaces g with some water: 1 x 3 x water. "No, it's not water. It's a chemical product: it combines with 1 and 3 and then it turns into a yellow liquid (he goes on to three-by-three combinations beginning with the replacement of g by 2 and by 4 -- i.e., 1 x 3 x 2 and 1 x 3 x 4). No, these two products aren't the same as the drops: they can't produce colour with 1 and 3 (then he tries 1 x 3 x g x 2). It stays the same with 2. I can try right away with 4 (1 x 3 x g x 4). It turns while again: 4 is the opposite of g because 4 makes the color go away while g makes it appear." -- "Do you think that there is water in (any of the) bottles ?" -- "I'll try (he systematicallyreplaces 1 and 3 by water, trying 1 x g x water and 3 x g x water, having already tried 1 x 3 x g ." No, that means 3 isn't water and 1 isn't water." He notices that the glass 1 x 3 x g x 2 has stayed clearaer than

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> 1 x 3 x g. "I think 2 must be water. Perhaps 4 also ? (He tries 1 x 3 x g x 4 again) so it's not water: I had forgotten that it turned white; 4 is a product that makes the white return."

It is not difficult to discern a distinct pattern of responses among the above mentioned responses of Swiss children who, it is believed, are above average in intelligence. (See the teaching plan at the end of this chapter). We now present some similar studies conducted in our part of the world.

Past work.

Vaidya (1964) investigated combinatorial reasoning among British adolescent pupil N=60,30 (case study approach) studying in a secondary modern as well as comprehensive school in Central London. He found that combinatorial ability is highly correlated with intelligence than with chronological age. They also committed arbitrary errors when they failed to grasp the basic essentials of the problem.

Vijayaluxmi and N. Vaidya (1966) found that backward pupils spent more time on the beaker problem. They were more nervous and needed more assistance. When assisted no significant difference was found between normal and backward children on the combinatorial grouping scheme of thought.

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M. Jain (1984) found that performance on combinatorial reasoning improved with age. Performance of girls was found to be better as compared to that of boys. Private school students were found to be better as compared to that of government school students. Other major results were that combinatorial reasoning was correlated with linguistic ability and intelligence. They also reported that personality traits led to the development of combinatorial reasoning in adolescents.

Bhati (1985), R.G. Sahu (1985) and Jal Singh (1986) used the paper pencil form of the combinatorial group of thought. They found that mean performance improved with grade, age (mental rather than chronological), sex differences favouring boys or girls exist in problem solving. The reason for this that samples for the above mentioned studies were drawn from rural areas as well as under-privileged homes. The pattern of the study followed that of Vaidya which is now discussed below:

BEAKERS PROBLEM

The Problem

There are four beakers on the table. They are labelled A, B, C, and D as shown in the diagram given

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below. A small distance away, there is another beaker Z. One day, Ram did an experiment. Ram took parts of the contents from beakers A, B, C, D and put them in another empty beaker K. After this, he took some liquid from beaker Z and put it in the beaker K. An interesting thing happened. The entire liquid in K turned yellow. After sometime, his friend Mohan came and enquired of his friend about the formation of the yellow colour in the beaker K. While answering this question, Ram forgot how he had done it. Now Ram carried out several experiments to obtain yellow colour in the beaker Z but failed. Your problem is to write down all the possible methods by which yellow colour could be obtained in the beaker Z. Please remember that you are to write down all the possible methods. Before you begin solving this question, please answer the following questions:

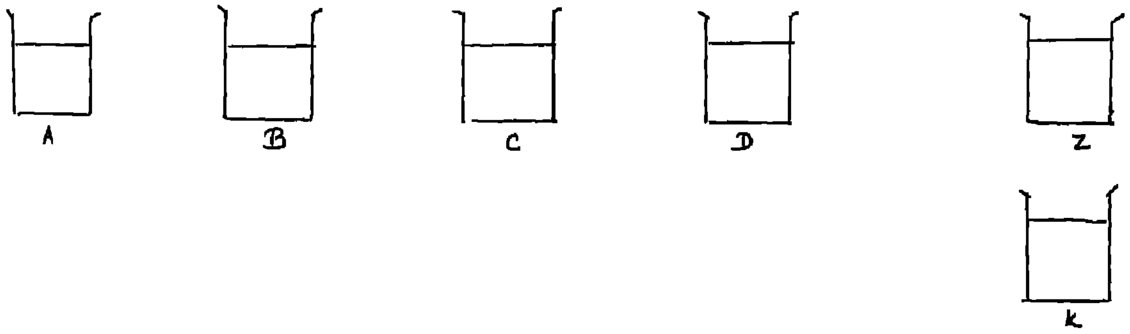

Fig. 2 : It shows the experimental set up of the paper pencil form test.

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(a) Have you done a problem of this type before ?

Yes/No

(b) Do you understand this problem ? Yes/A bit/No

(c) Do you find this problem difficult? Yes/A bit/No

(d) Can you solve this problem ? Yes/A bit/No

(e) Do you find any difficult word in this problem Yes/No

If yes, write only those words below:

Now solve the above mentioned problem.

Method No. 1 First of all, Ram took out some material from beaker A and put it in beaker K. After this, he took some material from beaker Z and put it in beaker K. Yellow colour did not appear. He did another experiment.

Method No.2

Method No. 3 and so on.

Manner of Presentation

The problem was presented as mentioned below. The arrangement of beakers: A, B, C, D, K, and Z was shown by placing six beakers on the table. The dropper was also shown for lifting the material from beakers. Method No. 1 was fully explained as one of the possible solutions to the problem. If the pupil did not understand it, he was allowed to read it again. Again the step was explained. It was ensured fully that everyone understood method number 1.

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Scoring

There are four processes involved in this problem which are relevant to the solution of the problem. These are:

(i)	Using one beaker at a time	Process No. 74 with three sub-processes.
(ii)	Using two beakers at a time	Process No. 75 with sixe sub-processes.
(iii)	Using three beakers at a time	Process No. 76 with four sub-processes.
(iv)	Using four beakers at a time	Process No. 77 with one process.
	Maximum score ½	14 marks, each sub-process carrying a mark each.

Vaidya utilized the beaker problem to find out the kind of groupings adolescent pupils make. The paper pencil test did not prove useful for pupils of grades VI to VIII. The main aims for investigvation were:

(i) Upto what extent can adolescent pupils structure essential requirement of the problem and attack to profitably ?

(ii) Upto what extent can they exhaust all possibilities while tackling a problem of this nature ?

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(iii) What arbitrary errors do they make while tackling a problem ?

Maximum possible score is 14

Presentation of data:

The data obtained from the study is being presented below:

Table: 1 Showing means and standard deviations gradewise as well as sexwise for various sub-samples.

S.No.	Grade	Sex	Mean	Standard Deviation
1	VI	Boys	1.30	1.23
	VI	Girls	1.55	1.36
		Boys & girls	1.431	2.60
2	VII	Boys	1.45	1.16
		Girls	1.20	.75
		Boys & girls	1.33	1.97
3	VIII	Boys	3.2	14.70
		Girls	.95	.87
		Boys & girls	1.58	3.40
4	IX	Boys	2.9	2.39
		Girls	2.8	1.70
		Boys & girls	2.85	4.36
5	X	Boys	4.8	3.23
		Girls	6.35	3.71
		Boys & girls	5.58	7.13

Table: 2. Acquisition of range of combinations gradewise as well as sexwise in terms of number pf pupil on exhausting the various possibilites relatigg to the beaker problem

Grade	Sex	0	1-3	4-6	7-9	10-12	13+
VI	Boys	7	13	-	-	-	-
	Girls	6	12	2	-	-	-
VII	Boys	1	17	2	-	-	-
	Girls	2	18	-	-	-	-
VIII	Boys	-	12	8	-	-	-
	Girls	5	14	1	-	-	-
IX	Boys	-	121	6	2	-	-
	Girls	2	8	10	-	1	-
X	Boys	-	2	16	-	1	1
	Girls	-	2	11	3	1	3
	Total	23	110	56	5	2	4

Table: 3: No. of combinations given gradewise as well as sexwise on four processes, namely, using one beaker at a time, using two beakers at a time, using three beakers at a time and using four beakers at a time.

Grade	Sex	Process No.1	Process No.2	Process No.3	Process No. 4
VI	Boys	14	7	0	5
	Girls	19	3	0	9
VII	Boys	7	3	2	17
	Girls	6	2	1	14
VIII	Boys	24	0	0	20
	Girls	4	0	0	15
IX	Boys	27	5	6	19
	Girls	27	11	6	16
X	Boys	51	18	11	20
	Girls	54	32	23	18
	Total:	233	81	49	153

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Incidence of Arbitrary Errors

Failure to grasp the essence of the problem results in all sorts of errors. Then they bring seveeral extraneous considerations into the problematic situation which are in no way linked with the solution of the problem. They were too diverse and hence too difficult to count. Quite a few are mentioned below:

I. Took contents from Z and put into K.

II At the last step, the yellow colour appeared.

III. how did the colour appear ? He did the experiment.

IV. Repeating or reproducing the illustration or the question if the illustration fails.

V. Giving combinations like: ACK, BCDK, ABCDK, etc. The role of beaker Z was ignored. Alternatively, combinations like ZK was given (K is an empty or collecting beaker only)

VI. Perform several experiments but nature of any experiment is not given. Alternatively, tried seveal methods and failed.

VII. Obtained contents from ABCD and boiled.

VIII. Drawing the diagram of a table and showing the positions of bottles on it.

IX. Give me an extra beaker. Then he forgot it.

X. (Comment) Either the beaker K did the trick or the mixing of four liquids.

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XI (Comment) I simply do not understand how contents in Z beaker change the colour.

XII (Comment) It is not known how the yellow colour appeared in the first instance.

XIII There is a suggestion or advice for Ram not to forget.

XIV. What is the business of the beaker K in the experiment?

XV. In fact, it is the duty of Ram to keep in his head the various experiments and tell them when asked.

XVI. I tell you the way, I am sorry it does not work now.

XVII. (Analogy and carry over effect of the illustration) in the second experiment, the colour did not appear because it did not appear in the first experiment.

XVIII. I will take the contents from the various bottles (beakers). I will try several combinations (but combinations are not given). If these do not work, then I will put yellow colour.

XIX. (Way out). I tell you the way. Empty the four beakers. Fill in them as usual. they put some yellow colour.

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XX. Transfer all the contents or liquids into the empty beaker K. Mix well. be careful ! Yellow colour will appear. If it does not, then put yellow water. Another response: cover it with yellow paper.

XXI. I tell you how the yellow colour can appear. I can guess that Z contains yellow colour. If not then, it is pottasium iodine. You can taste it as well.

XXII. (See the incomplete response). In the first method the colour did not appear because Ram did not lift materials from beakers B, C, D and Z. he ought to have done this.

XXIII. There is yellow colour in the beaker Z which is not visible.

XXIV. (Combination not clear) Put materials from the remaining beakers drop by drop into the beaker K. Then transfer this mixture drop by drop in the beaker Z. something or somewhere the yellow colour must appear (what is your combination?)."I do not know".

XXV. Poor Ram had to perform several experiments. Why? I tell you. Take an extra beaker and put some water and yellow colour into it. Ram only forgot this. For this only, he had to perform several experiments.

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XXVI. Take other beakers, say, D, E, F, G, H, then I, J, K, L, then M, N, O, P and so on. Put different materials and I hope the yellow colour will appear.

XXVII. Let Ram continue with this experiments. He should learn not to gorget. I wish him 'good luck'!

XXVIII. I am dead sure that beaker K contains some yellow colour.

XXIX. I can say that these are all chemical liquids: water, acid, alkali and even scents.

XXX. Give me some litmus papers: red and blue.

XXXI. If my method does not work, I will take large and larger quantities.

XXXII. It is a terrible problem. I have to think.

XXXIII. It is a tricky problem because even I do not know when the colour will appear.

XXXIV. Ram ought to have labelled the beakers (which were already labelled).

XXXV. K beaker may be containing yellow colour(magic) or the beaker Z may contain yellow colour. I can also say that even the beaker K could be of yellow colour. Or the liquid turned yellow because there was little dye or colour on the palm of Ram which fell into beaker K during experimentation.

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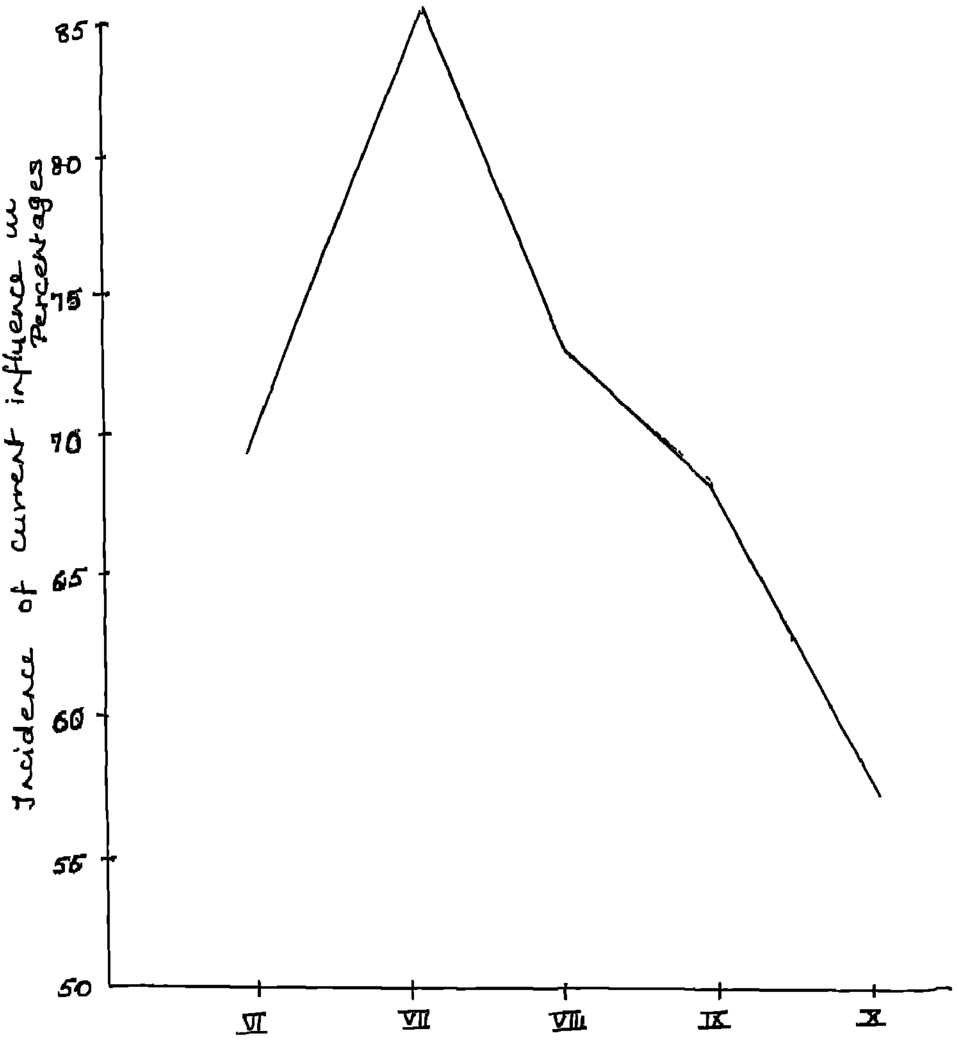
Discussion

Contrary to Piaget, it is strange to note that many adolescent pupils were led astray by the arbitrary errors committed in one form or another while tackling this problem. Even in grade X, the percentage of pupils so affected within that age group is as high as 57.5. There is another interesting observation. Throughout the grades, girls are affected more than boys as shown in the table given below:

	VI	VII	VIII	IX	X
Boys	65%	85%	60%	45%	50%
Girls	70%	85%	85%	85%	65%
Boys & girls	67.5%	85%	72.5%	65%	57.5%

Further analysis of the data shows that the grade percentage as well as sexwise percentages on the incidence of arbitrary errors arising on account of the failure to accept the problem also suffer a hump each. One of such humps is shown in Fig. 3.



Grades

Fig. 3. Hump on the incidence of arbitrary errors arising due to the failure to accept the demand of the problem

Several points of interest emerge. First, taking one beaker at a time, over 55 per cent of total combinations have been missed by the pupils of Grades VI to IX. Secondly, taking two beakers at a time. Over 73 per cent of the combinations have been missed by pupils of grades VI to X. Thirdly, taking three beakers

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at a time. Over 71 per cent of the combinations have been missed by pupils of Grades VI to X./ Fourthly, taking all the four beakes in any order. Only boys of grade VIII and X have not missed any combination. All of them were thus able to see the problem as a whole. the percentages of those both sexwise and gradewise who missed seeing the problem as a whole are given below:

	VI	VII	VIII	IX	X
Boys	75	15	0	5	0
Girls	55	30	25	20	5
Boys and girls	65	22.5	12.5	12.5	2.5

Except in grade VI, it is more of girls rather than boys who have missed seeing the problem as a whole. Decline of percentages across the various grades leads us to conclude that seeing the problem as a whole is mastered gradually.

Sample Responses.

Let us now mention below a few sample responses:

(i) G5, I.Q. 80, Grade VI, Score 0

Ram was a small boy. Beakers: A, B, C and D. Took materials from beakers A, B, C and D and put these into beaker K. Beaker K is empty. The yellow colour appeared.

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(ii) B 6, I.Q. 82, Grade VI, Score 0

Mohan inquired of Ram about the yellow colour. How did it appear.? Ram carried out certain experiments, his bad luck that yellow did not appear.

(iii) G 6, I.Q. 82, Grade VI, Score 0

First of all, Ram poured water into a beaker. After a short while, he found that yellow colour did not appear. He tried again. He took materials from beakers A and C and put that stuff into beaker K. The yellow colour did not appear.

(iv) B 15, I.Q. 107, Grade VI, Score 0

You see that there are four beakers. In beaker K, put some yellow dye. Put material from beaker A or B or C or D into beaker K. You will always see yellow colour.

(v) G 18, I.Q. 115, Grade VI, Score 0

Took material from beaker B and put that into the empty beaker K. It won't work. Take another yellow beaker and put that K material into it. It will just look yellow.

(vi) G 69, I.Q. 92, Grade IX, Score 0

I will proceed as follows. Ram should take water in two or three beakers and add yellow dye into one of these. Then transfer a small amount of materials from beakers A, B, C, D each into

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beaker K. Then add water from the remaining beakers. Yellow colour will appear.

(vii) G 30, I.Q. 95, Grade VIII, Score 1

Take four bottles of water (chemicals). The colour turned yellow because all the four bottles stood in a raw.

Took some materials from bottles A, B, C and D and put it into K. Then took out some material from beaker Z and put it into beakerK. The yellow colour may come.

(viii) G 38, I.Q. 115, Grade VII, Sore 1

I tell you the way. Take eight glasses of different colours: Yellow, red, green, blue, whitish and golden etc. Put materials from Beakers A, B, C and D into these beakers. The materials in yellow definitely look yellow.

We have four boxes, you see.

Two of us (pointing to a friend) did the experiment. We put materials into these boxes. Yellow colour did not come.

Let us now take four beakers, A, B, C and D. Take materials from each beaker and put it into beaker K. Then put some material from beaker Z into it. Now the yellow colour appeared.

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(ix) B 41, Grade VIII, I.Q. 70, Score 1

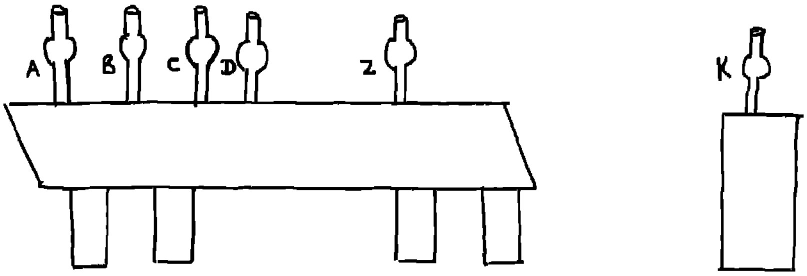

Fig. 4 -- One of the specimen responses pictorially.

I drew the diagram first. I have also shown the bottles. The empty bottle K is on a high stool. I took materials from beakers, A, B, C and D one by one and put that into the empty beaker K. Then I took out some material from beaker Z and put that into the beaker K. The colour turned yellow.

(x) B 20, I.Q. 120, Grade VI, Score 3

In a roundabout way suggests the following combination BKZ which is, in fact, BZK. there must be yellow colour in Z which is not visible to the eye. In C, it is whitish. I took a little colour from C, a bit more from Z and put both in the beaker K. Yellow colour should appear.

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(xi) G 95, I.,Q. 107, Grade X, Score 14

Ram took material from beakers B and Z and put into beak^er K. Yellow colour did not appear.

So he should take materials one by one from the beakers C and D. so the combinations are:

AZK, (already done)

BZK, CZK and DZK

The other combinations are:

ABKZ, ACKZ, ADKZ, BDKZ, CDKZ, BCKZ, (taking two beakers at a time.)

ABCKZ, ABDKZ, BCDKZ, ACZDK

(taking three beakers at a time)

Lastly, ABCDZK

(taking all the four beakers)

I think I have finished all the combinations.

I do not see any other combinations, still left.

Interpretation of discussion

What do they do when they fail to solve the problem ? They complicate it by bringing several extraneous considerations into the situation in which they then carry out quite complicate or far fetched reasonings in another otherwise simple situation, which are simply not blind. Even when they carefully read the problem along with the illustration that gives scent to the solution of the problem, they continue to rub the problem at the wrong end. It is, therefore,

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least surprising that when failure to grasp the essence of the problem in the absence of the corresponding cognitive structure or scheme of thought occurs, all sorts of solutions arise which range from repeating, rephrasing or repoducing the beaker through obtaining an extra or several beakkers using all the 26 alphabets to closing all the possibilities even once the understanding dawns that this particular solution must give the yellow colour. A few other helpful suggestions are also provided: be more careful in future, poor Ram should not have forgottten the experiment for he could well have written it, earlier, thus, avoiding trouble later on; emptying and re-emptying the various beakers; giving a few more chances to discover the solution; and committing the final experiment to memory. Apart from these, there are two other trends as well. First, why should 'yellow' does not ask or expect then to question just this part of the problem. Secondly, if they just accepted, the reason well could be some invisible colour in beaker Z (which could be a case of magic or jugglery) which appears in beaker K. If this is not, colour the K beaker yellow or wrap it is a yellow transparent paper. This solution amounts to using the basic information and concept underlying the science of colours. Our pupils just do not stop at this for they do further in their thinking, a distinguishing characteristic of their thought.

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If the preceding methods have not worked, why not boil the chemicals ? Why not use litmus papers or acids, alkalies, water and scents, etc. ? These proposals amount to physical and chemical experimentation to a certain extent. This is usually done in the laboratory while investigating an unknown substance. In this context, their consequent thinking on this problem is quite respectable for no option even external to the problem is excluded from consideration to crack it up. Chemical like drugs are labelled. Poison is clearly marked. Why ? For quick distinction! Whereas the psychologist has its own limitations, any scoring system should not set aside such approaches. For example, if no illustration is given, beaker Z becomes beaker F and joins it earlier partners. the solution to the problem then becomes very difficult for it becomes an open problem in which every option has to be suggested. This very problem may then throw up several arbitrary errors making, in the process, any distinction between meaningfull and arbitrary error difficult. The reason for this is that there are no extenal criteria against which a given option can be tested. This then necessitates either rephrasing the problem or imaginatively testing half the options with fewer and fewer control experiments. To cut short the discussion, our data abundantly indicated that the above

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mentioned arbitrary responses attempted at tackling the problem whether at the end solution emerged or not. This point is generally missed because solution to the problem is known to the psychologist. If the solution, unfortunately, is not known to the psychologist, distinction between relevant and irrelevant variable, in fact, ceases (the words easier said than explained) for they have to be shown so by the strength of general as well as (or) specific argument supported by observation or mathematics or both.

Main results

The results of the study indicated the following:

(i) Except a small fluctuation in Grade VII, grade means increase with age. Average performance favours girls of Grade VI and X whereas it favours boys of remaining grades VII, VIII and IX. The highest mean performance of grade X girls is less than half of the maximum score on this problem which clearly shows that most of the adolescent pupils are not in a position to exhaust all the possibilities inhering a combinatorial problem.

(ii) Contrary to Piaget, adolescent pupils are not in a position to exhaust all possibilities. Considering even a semi-maximum level of possibilities it is only in class IX and X that 40% and 67.5% of the pupils are

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in a position to do so. This ability to exhaust a half of the maximum possibilities exist little in grade VI, VII and VIII, the corresponding percentages being 0, 10 and 23.5. It is least surprising that about one third pupils of grade VI are not in a position to consider even a single possibility. In grade VII that is 2 years later even 12.5 per cent girls of that grade are not in a position to suggest a single possibility considering the pooled sample (N=200) Only 55% of the students are in a position to suggest only one two three combinations (possibilities) especially when one of the illustrations is provided to start their thinking on the problem.

Results for the four distinct processes of thought reveal the following:

(i) Taking one beaker at a time. It is only in grade X that almost all the pupils are in a position to exhaust all the combinations in that category. The percentage declines to 45% in the case of IXth grade pupils.

(ii) Taking two beakers at a time. Overall performance is poor. No student from grade VIII could suggest even a single combination of the type. Even in grade X the percentages of such combinations for boys and girls are 154% and 26.6% respectively.

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(iii) Taking three beakers at the same time. Here again the overall performance is poor. No combination came from grades VI and VIII. The percentage of such combinations by boys and girls of grade IX and X are 7.5 and 7.5 and 13.5 and 28.75 respectively.

(iv) Taking four beakers at the same time. Only 20 combinations sexwise were maximally possible in each grade. Only 76.5 percent combinations we~~^~~re given in this category. Except a single fluctuation in grade VII in the case of girls only, most of the combinations were given given by pupils of grades VII to X. In grade VI, the percentage of combinations given by boys and girls are 25 and 45 which are low. This may be due to single aspect of the problem which was in fact short circuted on this problem.

Lastly, let us see how this problem correlates with other 44 variables. It correlates insignificantly at the conventional level of significance with the following outside variables: social adjustment; understanding the problem; felt difficulty of the problem and interest in the problem. With all the other variables, it correlates positively and significantly. There are a few interesting observations as well. First, it correlates more with grade than with intelligence (correlations being .5439 and .3534).

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Secondly, it correlates more significantly with some problems and schemes of thought than with intelligence. some examples are: negative summation series problem, proportion problem, rectangular cube problem, combinatorial digital problem, questions involving wrong answers, nine dot problem, fish problem, spring balance problem, proposing tests problem, and us~ing constant difference, using summation, using proportion, using three digits at a time, genera~lisation to algebraic symbolic (proportion); stating procedure and proposing tests.

Satya Mehndiratta and N. Vaidya investigated only one scheme of thought, namely combinatorial grouping (reasoning) among 120 pupils in grades VI to XI, there being 20 pupils in each grade. The basic problem for ensuring its understanding was in paper pencil form (See vaidya,) and the Piagetian problem was demonstrated in small groups to the pupils.

The sample was divided into three groups on the basis of the achievement variable - high achievers, average achievers and low achievers.

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Presentation of results

Table: 4: Showing mean and S.D.'s of all the processes of beaker problem for all grades (V through X)

Name of the test	Processes	Statistics used	GRADES						
			V	VI	VII	VIII	IX	X	Total
Beaker problem	Com.1	Mean	2.55	1.80	1.65	2.00	2.00	2.80	2.13
		S.D.	0.82	1.28	1.38	1.25	1.12	1.15	1.15
	Com.2	Mean	2.10	3.40	3.90	3.30	3.20	2.15	3.00
		S.D.	2.15	2.16	2.26	2.26	2.32	2.32	2.27
	Com.3	Mean	0.50	1.05	1.80	1.55	0.95	0.85	1.11
		S.D.	1.05	1.19	1.50	1.43	1.05	1.34	1.32
	Com.4	Mean	0.30	0.35	0.7	0.55	0.55	0.22	0.44
		SD	0.47	0.48	0.47	0.51	0.51	0.41	0.49
	Com.T	Mean	5.45	6.60	8.05	7.40	6.70	5.95	6.69
		S.D.	2.91	3.15	3.83	3.61	3.31	3.76	3.49

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Table: 5: shwoing varimax rotated factor matrix as well as the Eign values for the three factors along with the pcercent of variance carried by each if the factors

S.No.	Variables	FACTORS I	II	III
1.	Using one beaker at a time	-	-	.78
2.	Using two beakers at a time	-	.82	-
3.	Using three beakers at a time	-	.75	-
4.	Using 4 beakers at a time	-	.60	- .36
5.	Rating by teachers on pupil's problem solving ability.	.66	-	-
6.	Overall achievment	.80	-	-
7.	Achievement in English	.68	-	-
8.	Achievemtnt in Hindi	.54	-	-.39
9.	Achivement in Mathematics	.70	-	-
10.	Achievement inSocial Studies	.52	-	-
11.	Category of pupils	-	.93	-
12..	Eign value	3.44	1.90	1.16
13.	Percentage of variance carried.	31.4	17.3	10.5
14.	Cumulative percentage	31.4	48.6	59.2

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The main findings of the study indicated.

1. There is a steady growth of combinatorial grouping ability with grades V to X with some fluctuations.

2. There are significant mean differences in high, average and low achiever groups of total combinatorial grouping thought for all the processes of combinatorial grouping ability.

3. There is no significant mean difference in achievement of social studies for three different groups high, low and average groups of combinatorial grouping.

4. The achievement in examination is having a positive significant correlation with the combinatorial grouping ability.

5. The achievement in school subjects namely, English, Hindi and Maths are significantly correlated with combinatorial grouping ability.

6. Correlation between combinatorial grouping ability and achievement in social studies is not significant. It shows that social studies is not helpful in development of combinatorial grouping ability.

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7. Combinatorial grouping ability is significantly correlated with problem solving ability. This shows that development of combinatorial grouping is helpful in solving problems of different areas.

8. Considering the entire sample and all variables using principal axes method and rotated by varimax three factors appeared, these are:

   1. Achievement in examination.
   2. Combinatorial reasoning -2.
   3. Combinatorial reasoning-1.

The present study

This study aims to see how students from class VI /(Age 10+) are able to solve the problems involving combinatorial reasoning. The total sample is 33 comprising of students from 2 schools of Delhi - Monther's International and Mirambika.
(N=25) (N=8)

The problems presented involved the student's ability to form different combinations. The problems were presented after the students had been able to solve certain simple problems (the equalizing experiences) on which nearly all of them were expected to perform well i.e. no failures were expected.

The tasks presented are briefly discussed below:-

(i) There are three boys B1, B2 and B3 and also three girls G1, G2 and G3. All 6 of them go for a dance party. Oly a boy and a girl can dance together. So, could you tell me in how many possible combinations a boy and a girl can dance together. Just write down all combinations that you can think of.

(ii) There are three numbers 6, 8, 9. You have to form both three digits as well as two digit numbers by using these numbers. Write down all the numbers which you can make by using these numbers.

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(iii) The beaker problem:-

There are 4 beakers on the table. They are labelled A, B, C and D as shown in the diagram below. A small distance away there is another beaker Z.

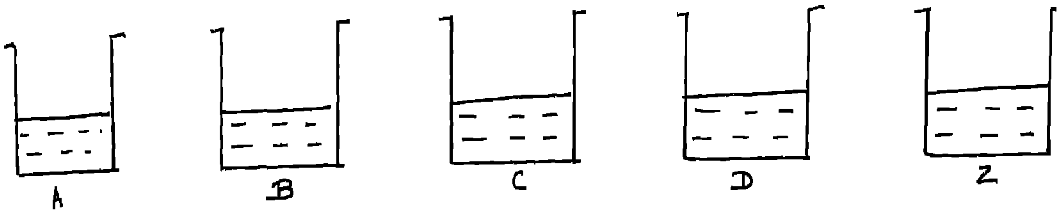
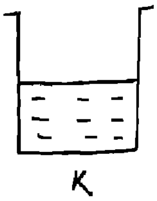


Fig 5



There is also another empty beaker K.

One day Ram did an experiment. Ram took parts of the contents from beakers A, B, C, D and put them in the empty beaker K. After this he took some liquid from beaker Z and put it in beaker K. An interesting thing happened. The entire liquid in K turned yellow. After some time, his friend Mohan came and enquired of his friend jabout the formation of yellow colour in beaker K. While answering this question Ram forgot how he had done it. Now Ram carried out several experiments to obtain yellow colour in beaker K but failed. Your problem is to write down all possible methods by which yellow colour could be obtained. Please remember that you have to write down all the methods.

Table : 6: Showing the scalogram of pupils responses (N=33) on Dance Problem.

S. No.	B1G1	B3G3	B2G2	B1G2	B2G3	B3G2	B1G3	B2G1	B3G1	Total
6	—	—	—	—	—	—	—	—	—	0
12	—	—	—	—	—	—	—	—	—	0
18	—	—	—	—	—	—	—	—	—	0
27	—	—	—	—	—	—	—	—	—	0
2	✓	✓	✓							3
4	✓	✓	✓							3
8	✓	✓	✓							3
14	✓	✓	✓							3
16	✓	✓	✓							3
10	✓	✓	✓	✓	✓					5
22	✓	—	—	✓			✓	✓	✓	5
3	✓	✓	✓	✓	✓	✓				6
24	✓	✓	✓	✓	✓				✓	6
1	✓	—	—	✓	✓	✓	✓	✓	✓	7
13	✓	✓	—	✓	✓	✓	✓	✓	—	7
17	✓	✓	✓	✓	✓	✓	—	✓	—	7
9	✓	✓	✓	✓	✓	✓	✓	✓		8
25	✓	✓	✓	✓	✓	✓	✓	—	✓	8
5	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
11	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
15	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
19	✓	✓	✓	✓	✓	✓	✓	✓	✓	9

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S.No	B_1G_1	B_3G_3	B_2G_2	B_1G_2	B_2G_3	B_3G_2	B_1G_3	B_2G_1	B_3G_1	TOTAL
20	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
21	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
23	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
26	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
28	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
29	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
30	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
31	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
32	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
33	✓	✓	✓	✓	✓	✓	✓	✓	✓	9
Col. total.	28	266	255	2323	22 221	20	20	20	19	209
No of errors	0	1	0	1	1	1	1	2	2	11

Coefficient of fluctutation $= \frac{11 \times 100}{209} = 5.28$

Coefficient of reproducibility = 100- 5.26 = 94.77

Table 7: showing the scalogram of pupil responses (N=33) on number formation problem

S. No	68	69	86	89	96	98	986	869	896	689	698	968	Total
13													-
1	✓	✓	-	✓									3
20	✓	✓	✓	-	✓	✓							5
2	✓	✓	✓	✓	✓	✓							6
3	✓	✓	✓	✓	✓	✓							6
5	✓	✓	✓	✓	✓	✓							6
6	✓	✓	✓	✓	✓	✓							6
15	✓	✓	✓	✓	✓	✓							6
8	✓	-	-	✓	✓	✓	✓	-	✓	✓			7
24	✓	-	✓	✓	-	✓	✓	✓				✓	7
21	✓	✓	-	✓	✓	✓	✓	-	✓	-	✓		8
25	-	✓	✓	-	-	✓	✓	✓	✓	✓	✓		8
4	✓	✓	✓	✓	✓	✓	✓	-	✓	✓			9
17	✓	✓	✓	✓	✓		✓	✓	✓	✓			9
23	✓	✓	✓		✓	✓		✓	✓	✓	✓		9
31	✓	✓	✓	✓	✓	✓	✓	✓		✓			9
10	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	10
16	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		10
18	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	11
22	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	11
26	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	11
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12

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NO	68	69	86	89	96	98	986	869	896	689	698	968	TOTAL
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	12
al	31	29	29	29	29	28	23	22	20	20	19	12	301
of ors	1	2	2	3	1	3	2	2	2	3	3	3	27

$$\text{Coefficient of fluctuation} = \frac{27 \times 100}{301} = 8.97$$

Coefficant of reproducibility = 100 - 8.97 = 94.74

Table 8: Showing the scalogram of pupil responses on the beaker problem

S. No	AKZ	BKZ	DKZ	CKZ	ADKZ	ABKZ	ACKZ	BCKZ	BDKZ	CDKZ	ABCKZ	ABCDKZ	ABDKZ	BCDKZ	TOTAL
2															0
6															0
19															0
20															0
21															0
22															0
4	✓														1
12	✓														1
3	✓		✓												2
25			✓	✓											2
11	✓				✓										3
13	✓	✓	✓												3
16	✓	✓	✓												3
32	✓	✓		✓											3
8	✓	✓	✓	✓											4
23	✓	✓	✓	✓											4

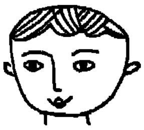
	AKZ	BKZ	DKZ	CKZ	ADKZ	ABKZ	ACKZ	BCKZ	BDKZ	CDKZ	ABC-KZ	ABCD-KZ	ABD-KZ	BCD-KZ		TOTAL
24	✓	✓	✓	✓												4
30	✓	✓	✓	✓												4
31	✓	✓	✓	✓												4
18	✓	✓	✓	✓				✓								5
17	✓	✓	✓	✓				✓								6
26	✓	✓		✓				✓								6
29	✓	✓	✓	✓	✓		✓									6
5	✓	✓	✓	✓	✓	✓	✓									7
15	✓	✓	✓	✓	✓	✓	✓									7
27	✓	✓	✓	✓	✓	✓							✓			7
10	✓	✓	✓	✓	✓	✓	✓		✓	✓						9
14	✓	✓	✓	✓	✓	✓	✓	✓	✓							9
33	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						10
28	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					11
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				12
9	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				12
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			13
[illegible]	26	22	22	21	12	10	9	7	9	7	9	4	3	2	1	158
Errors	1	0	4	1	1	0	3	1	3	1	1	0	0	1	0	

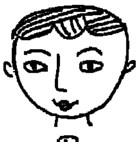
Teaching schemes

Dance problem

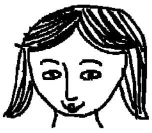
I.

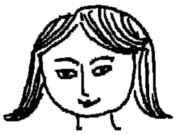
We have 3 boys.





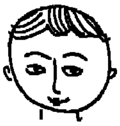
and 3 girls





All of them go to a dance party. Only a boy and a girl can dance together. In how many pairs can they dance ?

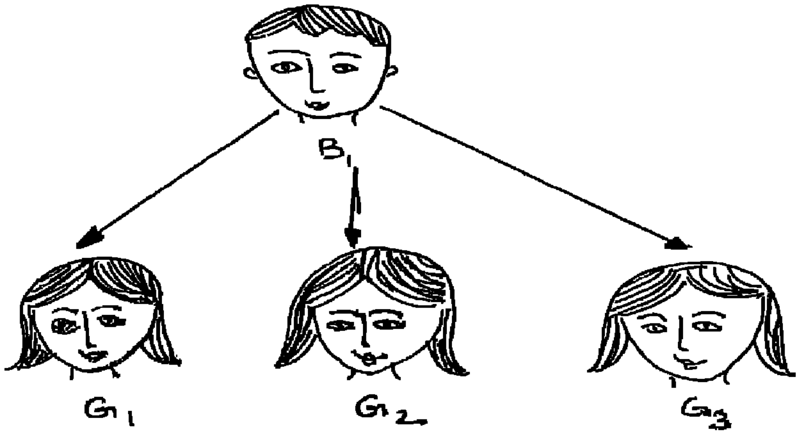
one pair is B1, G1



Can you think of the other pairs ?

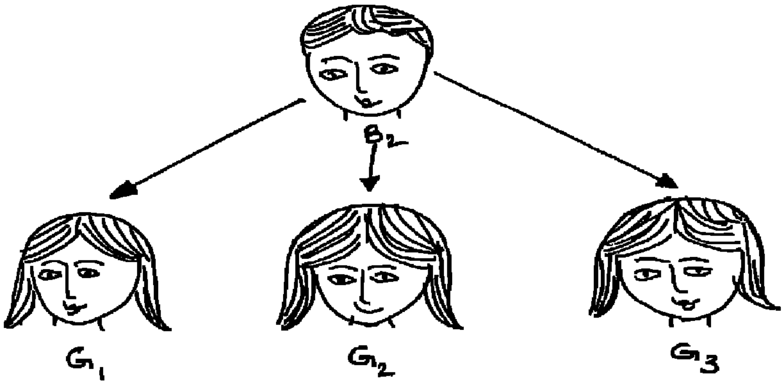
Look how you can form the other pairs.

I.



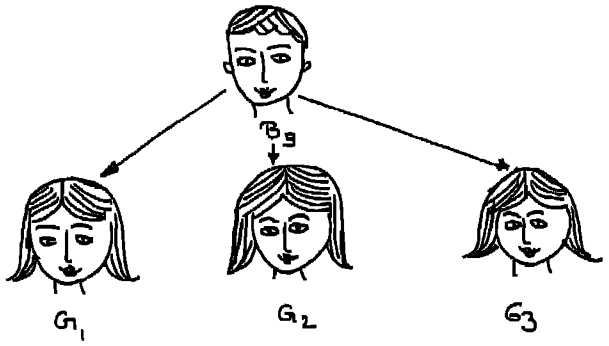
i.e. B1 G1, B1 G2 , B1 G3

II.



i.e. B2 G1, B2 G2 and B2 G3

III.



i.e. B3 G1, B3 G2 and B3 G3.

B1, B2, B3 and G1, G2, G3 can dance in 9 possible combinations.

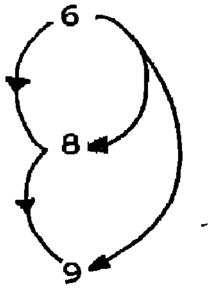
Teaching scheme:

II. Formation of Numbers:

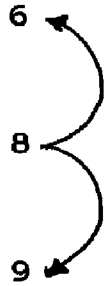
There are 3 numbers 6, 8, 9. You have to form 2 digit and 3 digit numbers using these 3 numbers. One number would be 68.

How do you form the other numbers?

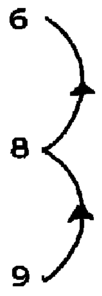
Another number you can form is 69. Look how you can form the numbers.



68, 69, 689, 698



86, 89, 896, 869



98, 96, 986, 968

the numbers formed in all are 12.

Now rewrite these numbers in a systematic manner.

Lastly, it is stressed that teacher should not impose his own framework of thought on children's thought process. Any idea which the child develops on his own is of lasting values. To quote -

> "A man's mind stretched by a new idea can never go back to its original dimensions."
>
> (Oliver Wendell Holwes)

8

2. Teaching for The exclusion of variables

2. Teaching
for
The exclusion of variables

Introduction

It is a world famous problem which has been used by several workers all over the English speaking world. For investigating the thinking process of adolescent pupils it is an ideal problem for ascertaining the extent to which the sixteen binary operations appear during adolescence. Using the Piagetian version of the problem in its basic essential let us see how the solution of this problem is obtained. Before this is done the main objective of the study is whether the pupils can manifest formal reasoning, using a series of thought provoking problems. In other words, whether under certain conditions their thought processes can be accelerated. Secondly, it is to suggest a teaching plan. Before this is done let us see:

(i) How the solution of this problem is attained in the higher age groups.

(ii) How training helps in the acquisition of "Exclusion of variables" scheme of thought and that too in the higher age groups.

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Study by Vaidya

(The Simple Pendulum Problem)

Introduction

The present study was conducted in two parts on secondary school going British pupils who were studying in a Secondary Modern School in Central London. They were not academically minded and their intelligence quotients varied from 80 to 110 on the 11 + test. Most of them came from less than average socio-economic status families and broken homes too. They were too noisy and too difficult to discipline or control by their teachers. Hardly any of them was to appear in the R.S.A. as well as G.C.E. 'o' level examination later on. In the first part of the study, the questionnaire approach was used (N=60); and in the second part of the study, it was the case study approach i.e. the individual made of administration (N=31).

On reading the problem, it becomes apparent that the problem is quite difficult, because it involves excluding variables one by one through control experiments. The variables involved are (1) fixed time, (2) weight of the bob, (3) volume of the bob and the amount of swing sideways. At the same time, it also involves visualizing bobs of different volumes but of the same weight and vice versa. As conservation of weight follows conservation of volume in intellectual development, the above-mentioned variables interact and interfere with the

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thinking of the fourteen fifteen-year adolescents. It is shown by their performance on this problem, especially, in view of the fact that this experiment was set up, demonstrated and explained . This problem otherwise would have proved too difficult to understand.

I am showing you a simple pendulum. The number of swings this pendulum makes may depend upon --

1. The length of the pendulum. You can measure its length.
2. The length of the swing sideways. You can change this amount of swing by starting the bob from different positions which can be marked on the floor.
3. Weight of the bob. You can weigh the bob.
4. The volume of the bob. You can find its volume.
5. The length of time for which this pendulum swings. You can read time from your watch.

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Your problem is to set up experiments to show which of the above things 1 - 4 are important timing and which are unimportant . How will you get rid of the above factors (variables) (1 to 4) one by one, and thereby make your judgement on each one of them ? I will write down the first step for you.

First Step. To get rid of the length of the pendulum, I would perform the following experiment -

Experiment 1

I would get a length of string with a ball on it. I will measure its length on a ruler. I will hand it up, pull the bob to one side and count the number of swings it makes in one minute. I will mark the point sideways at which I released the bob for swinging. I would now make the string longer, use the same bob, release the bob from the same marked point and again count the number of swings it makes in one miniute. I would write down this second as well. I would now shorten the length, use the same bob, release the bob from the same marked point and record the number of swings it makes in one minute. Now I have to make a conclusion. I know all the three counts. If the three counts are different, then I will say that different lengths give different numbers of swings in one minute. If the three counts are the same, then I would say that

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length does not affect the number of swings in one minute. Thus I would know the effect of length on the number of swings on my pendulum.

Now proceed to get rid of the following:-

(1) Weight of the bob ;

(2) Volume of the bob;

(3) Length (amount)of the swing sideways (amplitude)

Anything else that you require for your experiments is supposed to be available.

Aims of this problem. This problem involves isolating the following factors or variables.

(1) Time. It has to be kept constant, at least, for any set of observations.

(2) Weight of the bob. This involves changing weights of the bobs (three times at least) keeping all other factors the same. Other factors are time, length of the string, volume of the bob and the amount of swing sideways.

(3) Volume of the bob. This involves choosing bobs of three different volumes but always of the same weight, and keeping all other factors the same.

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For our purpose, it does not matter if a set of three different experiments is set up to isolate a particular variable.

No hint is given on this problem. The other features of presentation are:

(1) Experiment (1) was redemonstrated and re-explained in the light of subjects' questions.

(2) They were in fact, encouraged to ask questions.

(3) They were asked to tell their difficulty and what they were thinking about.

Scoring. It is as follows:

(1) Keeping time constant or counting for one vibration.
= one mark

(2) Isolating the following factors by setting up control experiments for

(a) weight of the bob
= two marks each
(b) volume of the bob
(c) length of swing sideways

Total score = seven marks

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Analysis of the problem Solving Process

53 per cent of the pupils could not attempt this problem. Another 15 per cent did attempt this problem but could not attack it at all. All this happened over a wide I.Q. range. The remaining 32 per cent did attempt it to a varying extent. Among them, only about 12 per cent could attain the full slution. What, therefore, remains important to us are the distinguishing features of their sequence of reasoning. It is somewhat as follows:

(i) I would take the bob off and weigh it and see how much it swings without the bob and measure the difference. I would find the volume of the bob and take it away from the swing. Make the swing and measure the distance.

(ii) I would change the bob to a different weight by using a lighter bob. The volume of the bob would change automatically when I put a lighter bob on the pendulum. If the bob was ligher, it would not swing as far as the heavy bob.

(iii) I would say that the weight of the bob is important and the length of the string. Because without the weight of the bob, the pendulum would not be any good. And the length of the pendulum swings.

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(iv) He is a bit repetitive and then he says, "I would get a length of string with a ball on it. I will measure its length on a ruler -- I would hang it up, pull the bob to one side and count the number of swings"

(v) I would weigh the bob and then weigh the whole lot and take it away and see how manyswings. Volume of the bob is ____, you know.

(vi) A very long string, a heavy weight and pull it a long way, about a foot.

(vii) If you would measure it with a ruler and answer 120 cm.

(viii) Measure the swing on the ball, swing the weight and mark and count the number it swings and makes in one minute.

(b) The second feature is the awareness of time, i.e., fixed time or count. Along with it is the consideration of three weights which should be different. But in this case, they have forgotten the role of fixed volume. However, for the purpose of scoring, we have given them the benefit of doubt. One interesting thing to note is that after isolating thefactor of 'weight', there is evidence to test the factor of 'length' again.

.......9

Consider this response:

> "I would get a piece of string of a certain length and put on a bob (3) each of a different weight on the string. Then I would time each weight to see how many swings it makes a minute. I swing from the same place. Then I would draw a conclusion by knowing if each weight is the same or not. If these are the same then I would know if the length of the string matters or not. For this, I will increase the length and test."

He retests experiment No. (1)

(c) After isolating the fact^or of weight, there is the tendency to consider three different volumes but weight staying the same. Similarly, the consideration for the length of swing also comes in. Consider these responses:

(i) I would get a fixed weight and tie it on the end of a string. I would tie the other end so that the string can swing freely. I would swing it from a mark on the board and time it. Then I would change the weight only. Swing from the same point on the board and time it. Then I would do it again with another weight. If the time it took to make a swing was the same in all cases, I would know it

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affects the swing."

Expt. 3 to isolate volume:- "I would set up like last time only instead of swing and different weights I would use bobs of a standard weight but different sizes. Then I would swing them from the same mark, and see if it affected the swing. Expt. 4 to isolate length (amount of swing). "I would use a fixed weight and length of a string and would swing it from different places on the board. If the results of the time of each swing were different that would prove it affected the time of the swing.

I would put a bob on the string and swing it and see how many swings in a minute. I would then put another heavier bob on and do exactly the same procedure. Again with the third, I would put a still heavier one on. If the counts are different, then each weight gives a different number of swings. If they are equal then the different weights do not affect the number of swings. Again I would take three volumes of he same bob and do exactly the same procedure. With the length of swing, I would make two points either end of the string and see how many times the swings touch the point. With the second and third method, I would move the fixed point.

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iii) I would change the weight of the bob to three different weights and on three, make the experiment in the same amount of time and in the same positions. If three are different, weights give different number of swings in one minute. (2) The same expt. only this time changing the volume of the bob (same) three times. (3) Change the amount of swing three different times, the length of swing sideways changes the effect of the number of swing of my pendulum in one minute."

More than two-thirds of the pupils fail tosolve this problem. It is a poor performance on this problem where only 12% of the pupils completely solve this problem, especially in view of the fact that the experiment number (1) provides sufficient background information to solve practicallythe whole of the problem. The reason for the failure to solve this problem may be the concepts of conservation of volume and weight have interfered with their (pupils') thinking processes. According to Piaget, the conservation of volume follows the conservation of weight in intellectual development but the age at which we are considering these concepts (or schemata), these are supposed to be well developed among our pupils.

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INDIVIDUAL STUDY

Manner of presentation: No hint is given on this problem. Pupil's difficulties in regard to the understanding of the problem were clarified. Experiment No. (1) was explained, demonstrated and redemonstrated.

Growth of the Solution of the Problem

This is seen to be as follows:

(a)	No. of those who could not do the problem at all.	.. 16
(b)	No. of those who made arbitrary errors.	.. 25
(c)	No. of those who understood the significance of fixed time.	.. 15
(d)	No. of those who isolated one variable only.	.. 1
(e)	No. of those who isolated two variables only	.. 1
(f)	No. of those who isolated three varaibles only.	.. 6

The solution of this problem can be discussed under the following headings:

Discussion

(a) Extraneous and arbitrary considerations.

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(b) Grasping the essence of the problem on the basis of some quoted cases.

(a) Extraneous and arbitrary considerations. While engaged in solving this problem, many extraneous and arbitrary considerations turned up right from the academic group right down to the remedial group. These considerations are quite irrelevant to the solution of the problem but in a way resemble the non-essential part surrounding the root of a living plant.

The detailed growth of the solution is shown as under:

SIMPLE PENDULUM PROBLEM

No. Solution. (N=16)	Extraneous & arbitrary considerations (N=25)	Essential grasp			
		Fixed time	Weight	Volume	Amplitude
	Examples. (1) Guesses wt. of the bob. is 4 oz. and radious ¼", (2) Cut off the bob & cut off the string. ~~Ma~~ Make it longer and smaller. (3) It goes fast, it goes slower with heavy bob it goes slower. (4)[illegible]ere the s swing. In fact, I was thinking of the policeman all the time" (Bob) (5) "Get a cup of water and put in it to find the volume". The moving bob will injuremy eyes". "It is stupid ;to see the ball(going) like this."" It can goas much as you like." "You can stop it:., etc. (6) "I look stump on this problem ...:"etc.	N=15	N=1	N=1	N=4+2=6

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of the bob by cutting on the bob from the string". "Of course, I will have nothing to swing except the string". "I can't proceed further". He then plays.

Grasping the Essence of the Problem

Those who have solved this problem became aware immediately of the importance of fixed time or count after a few trials of the experiment number (1). They, then, ask for a stop watch. They are, then, asked dto give their method and thereby explain the consequences of the control experiments. The way theymake judgments is more important to us than the recording of actual observations. The latter are in fact discouraged, if they do not support or reject their chain of reasoning. Thus, 16 pupils could grasp the importance of fixed time. It is immaterial whether they calculate time for one oscillation or always keep the number of oscillations fixed.

Choosing suitable bobs turned out to be quite difficult. Concepts of bobs having same weight but different volumes and vice versa tended to block their thinking for a long time. They sat silent with pencil in their mouths and appeared to have turned deaf even when asked: "What are you thinking now?" They appeared to be all forgetful and then started stating their methods. They felt a lot of diff iculty in expressing their methods

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and sometimes their chain of reasoning was so fast that it was very hard to follow. In a way, they appeared to have grasped the essentials of the problem when questioned; for example:

"For getting rid of the weight of the bob, youwill take string of what length/lengths?"

"What about amplitude?"

"What about volume?"

"What abount count?"

This was ascertained for all the variables. They were then asked to state their methods. A fewe extracts follow:

Kerry

She asked for redemonstration of experiment No. (1). She then kept mum for fifteen minutes. Then the following question was put.

"What did I do in the first experiment?"

You used different lengths.

She made gestures for weight and volume, with her hands but could not suggest anything. "I think"., she said," I can think for the amplitude."

How ?

"Change amplitudes, i.e., drop more and more from the sides."

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Greenland

He first guesses that the weight of the bob is 35 gms. He then takes the apparatus into the corner and reads experiment No. (1). He then asks for redemonstration.

"My count is for 20, I suppose/" he then waits and thinks. Then he mutters to himself.

"Small weight - small volume - No.
Small volume - small weight - No.
Same bob.

Small volume
medium volume
large volume
swing same
string same".

His retrospectdive solution is reproduced below.

"To start, I said shorten the string, but I was doing experiment 1 and not 3. Then I said lengthn the string but I was still doing experiment 1 and not 3. Then I said, measure the length of the swing by starting off at the same point. Then (see) I thought of swinging it slower and slower."

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Linda

She was the quickest to solve this problem. She asked for redemonstration. She then repeats experiment No. (1). She then changes both length and weight but immediately correct herself bysaying, "string stays the same." Immediately, then, she states control experiments for the other two variables. Her solution is quoted below:

> "Get the bob on the length of string. Count the swings. Increase weight of bob , but keep both length of string and position of swing same. Count swings. Decrease weight of the bob, keep length of string ad position of swing same. Count swings. If swings in oneminute are same, weight of ball does not matter. If swings in one minute are different, weight of bob matters."

Similarly is handxcled the "volume" factor for isolation. It is seen that the concept of fixed time (count per minute) is the first must for solving this problem (See Bacrms case). As soon as this factor is isolated, considerations for other variables emerge. It is also abundantly clear that cues from the experiment No. 1 are not utilized straight away. In other words, these cues are utilized by those who can visualise those

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pupils who are in a position to visualize that the balls or bobs of the same weight but of different volumes; and the other way around, exist. The variable of weight is isolated first before he variables of volume. The last variable, that is, the "amplitude of motion", does not offer any special difficulty because the bob is to be released from three different heights.

The present study

(The acceleration of thought process
on
The simple pendulum)

Outstanding result

Our ten year old pupils came from a well known private public school (N=33) . Their overall achievement and socio-economic status were above average. Some of the pupils (N=8) had undergone unique experiences where they were freee to choose their own activities in accordance with their interests and inclinations. Whereas they were seeing part of the problem clearly in relation to the equalization of experience (Handkerchief problem which was not scored) and the simple pendulum problem where their responses were to be scored as per our criteria. No one was able to solve this problem even when it was affirmed firmly

(i) The length of the string can change.

(ii) The weight and volume of the bob can change.

(iii) It is possible to choose bobs of three different volumes but having the same weight.

(iv) It is possible to have three bobs of different volumes but having the same weight.

(v) Similarly, the amplitude of motion can be changed by releasing the bob at different heights.

Under the circumstances, they perhaps needed more experience with simpler problems.

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Our experience with These two problems

What is our experience with these two problems which have been investigaged by us over a very long time and where samples have been drawn from different parts of the country(Indian, Nepal and Uganda) ? The problem of "The Combinatorial grouping" and "The Oscillation of a pendulum and the operations of exclusion" related according to Piaget, to the operational schemes of formal logic (one chosen out of nine) and the development of propositional logic (one chosen out of six) respectively.

(1) The first problem is easy whereas the second one is a difficult nut to crack. For each scheme of thought, we finally selected quite a few problems inhering more or less the same logical structure.

(2) It is not difficult to arrange these problems in their ascending order of difficulty. When this is done even in a rough manner, it keeps us whether thinking on these problems can be accelerated or not. The pattern of response is discernible.

(3) Adolescents do not tackle the problems systematically. However, if experimental problems are selected, it is a good practice to let them "mess" about. Later on, it is within their capacities to describe the general mode of approach to the solution of the problem.

One can see this happening remarkably as soon as (when) their individual minds become experimental. The age at which this happens is just past midadolesence i.e. after the age of fourteen years. In those countries where teaching is done orally or through chalk and talk methods, the figure of 14 + goes up to as high as eighteen.

The choice of the problem is critical in investigating thought. It is a good practice to starting with simple problems for which experimental materials are easily available. Take Piaget's problem on "Combinations of coloured and colourless bodies"" (liquids). We made it a paper pencil test. The problem became difficult. We then put it into the form of digits: 6, 7, 8, 9 or 6, 8, 9. They were able to find/detemine figures. Finally, we reduced it to boys and girls who wish to dance and where only boy and girl can dance together. Here the problem becomes of human interest. "Have you missed any pair , "can be the general question which can be raised. It can be a practical strategy which is so natural and effective at the same time. Still, the underlying logical structure cannot be wished away for it has to be negotiated bythe adolescent pupil some how?

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It was seen prominently when we used the "Simple pendulum" problem. Several problems were considered. The "flow of water through a tube had a special appeal. But the results on the whole were more or less disappointing. If they learnt to solve one problem, they found it diffcult to apply the same/similar mode of reasoning to another problem, say, the bending of rods problem. They could hardly see the variation of a given variable. So it is better to select one and one variable at a time; and show its variation by keeping all other variables constant (see the handkerchief problem) where

(i) length can change

(ii) width can change

(iii) thickness can change

(iv) colour can change

(v) colour can be different

(vi) nature/material can change

(vii) time can change but has to be kept reasonably constant for the experiment to succeed.

(viii) Equality of sun or shade has to be ensured. And so on.

And, it is not at all a single shot effort.

(ix) The pattern of errors on almost all the problems is clearly more discernible than the pattern of the attainment of solution. This happens when pupils

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at three or more levels of mental development are in the sample. So a teaching scheme is implicity available which is hardly made explicit. Why ? The reason that the teacher always insists on the right answer.

What is implied from the above is that there is a close association betwen the problems based on propositional logic and operational scheme as judged bythe correlation between the scores on these two problems especially when these begin to be solved reasonably well. This view is further strengthed by our futher results which show that all Piaget and Piaget type tasmks correlate positively and significantly. To quote the Piagetian hypothesis:

> ....close relation exists between the mode of organization or the overall structure of the combinatorial operations on the one hand and those of the formal or the interpropositional operations on the other. At the same time that the subject combines the elements or factors given in the experimental context, he also combines the propositional statements which express the results of these combinations of facts and in this waymentally organizes the system of binary operations consisting the conjunctiions, disjunctions, exclusions etc. But this coincidence is not so surprising when we realise that the two phenonomene are essentially identical. In other words, the system of propositional operations is, in fact, a combinatorial system, just as from

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> the subject's point of view, the only purpose of the combinatorial operations applied tothe experimental data is to make it possible for him to establish such logical connections."

This whole thing is very very close to the Piagetian 'g' when contrasted with the Spearman's 'g' . The problem then remains that of paralling the affective development as well as the use of Piagetian logic as a tool, for the analysis of familiar experiences in our day to day lives. It means that the developmental trend as discerned has to be analysed psychometrically within the context of Piagetian theory.

Teaching Plan

Background. Despsite the failure of this experiment of controlled experimentation, it is highly desirable to introduce pupils to controlled experimentation towards the closing stage of the concrete stage of mental development. It is possible to identify and finally select, even on tentative basis, in the ascending order of difficulty as many experimental situations as possble on this theme. It is an observation which is highly relevant to the several schemes of thought. It is equally interesting if problems of daily concern are also tackled that way, superstitious also,

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of course, not excluded from purview. To quote some examples:

(i) Out of several advertised tooth pastes, which one will you finally choose to buy, say for the same price?

(ii) Out of the several available edible oils, which one will you choose, say for children, adults and the aged, sayfor the same price ?

(iii) How will you travel fast enough as well as the cheapest enough from Shimla to Kanyakumari within a budget of three thousand rupees, say, for a period of three weeks. We assume that fares of air, train, bus and living expenses vary from place to place. Also list the places of tourist interest which you would visit too.

Teaching plan

It comprises the following steps:

(i) Pose the problem in the solvable form.

(ii) Tackle successfully part of the problem under similar diverse conditions.

(iii) It is observed that measuring 't' (no of oscillations per unit time) is the basic prerequisite to understand the simple pendulum problem. Ask children to measure 't' for different lengths (pendulum) as well as weight as well as

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2/3

volumes of bobs and amplitudes, that is, release of the bob at different heights.

(iv) Vary the variable under study as widely as possible for dramatic results. Let each one of them (pupils) have the vague notion of what is happening.

(v) Raise such questions as:

1. Can we change the length of the pendulum?
2. Can we change the weight of the bob?
3. Can we change the weight of the bob but keeping the volume of the bob same ? How ?
4. Can we do the same thing for the volume of bob?
5. Can we release the bob at three different heights ? Can we control the weight and volume of bob ? It turns out to be a very simple question because except the amplitude, all other factors remain the same. But it offers difficulties for the pupils.

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Teaching Scheme

To length - I am going to show you a pendulum.

The bob is released at the point 'A'. Count the No. of oscillations made in 5 minutes. Calculate the No. of oscillations made in one minute. Write down your answer.

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2. Again look at the pendulum I am now releasing it from the point 'B' (At a higher distance/level). Again count the number of oscillations in 5 minutes and calculate the number of oscillations made in one minute. Write down your answer.

3. Still at higher distance, again count the number of oscillations made in 5 minutes and calculate for one minute. Write down your answer.

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Now your answers/results are when pendulum is released from 3 different points.

What do you conclude from the above mentioned three experiments. Encourage them through appropriate questioning arrive at the following conclusions. All other things remaining the same, the time taken for one oscillation does not matter.

Further check

I will show you another pendulum. I am doing what I did in the previous experiments. Can you predict the results of this experiment.

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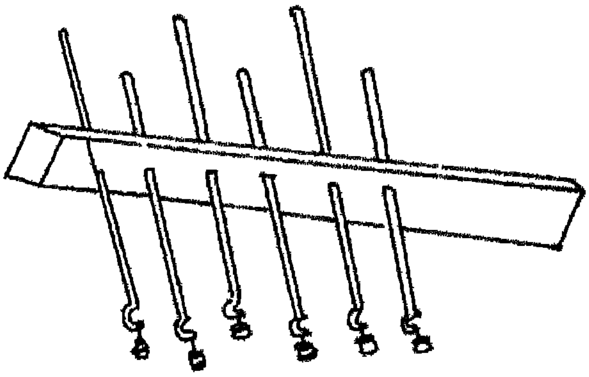
There are other problems which can be introduced to children for stating the hypothesis.

1. The bending rods apparatus -

The apparatus of a block of wood on a stand that has six metal rods inserted into it. The variables involves are (adjustable) length of rods, thickness, type of metal (brass or steel) shape (square or round), and amount of weight that is hung on the ends of the rods. Rods are referred to in the text by the abbreviations in the figure below, e.g. long b vs st means s compared the thin brass rod with the thick steel one, the brass rod was longer, and s used equal weights.



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The flow of heat through a rod on which pebbles are fixed:

This is another problem. If requires the pupils to determine the factors on which the falling down of the pebbles (fixed with the help of wax) will depend, (see fig)

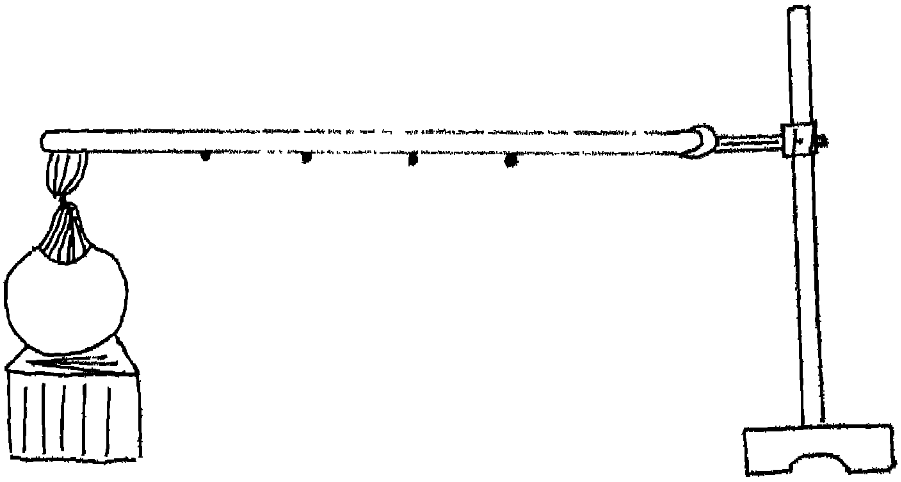

Fig 4

The ramp problem

Look at the diagram very carefully.

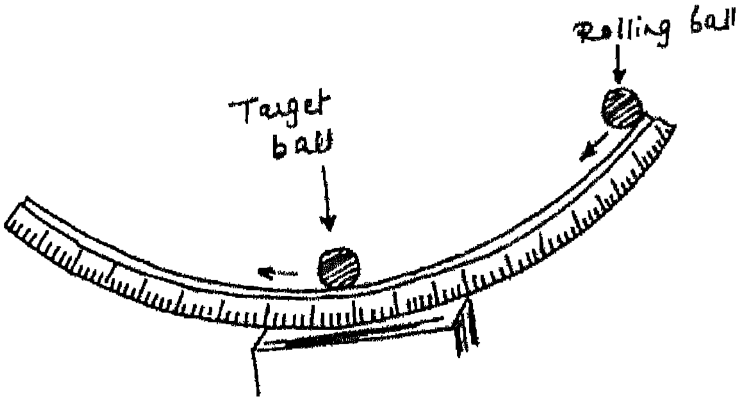

Fig 5

There is a ramp with a groove along which sphere can roll up and down. A target sphere is placed at the centre of the ramp, when another (rolling) sphere is released from the right (see the diagram). It rolls down the ramp, strikes the target sphere and makes it move up on the left.

The movement of the target sphere on any ramp depends on the following factors-

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1. Height of release of the rolling sphere.
2.
3.
4.
5.
6.
7.
8.
9.
10.

A student of your age wanted to know how worms move about in light and moisture. To solve this he placed 20 worms in the centre of each of the four glass boxes under different conditions of light and moisture. For moisture, water was sprinkled on the bits of paper in the whole box or in half the portion of the box as required. Light was provided by the electric bulb to the required part of the box. His data are shown in the four diagrams given below. Your problem is to have a close look at each of these diagrams and reach a suitable conclusion. You are free to suggest any other experiment, if it might help to solve the problem clearly. It is also possible that the above mentioned student have missed an experiment or two.

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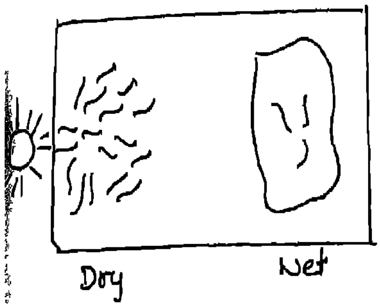

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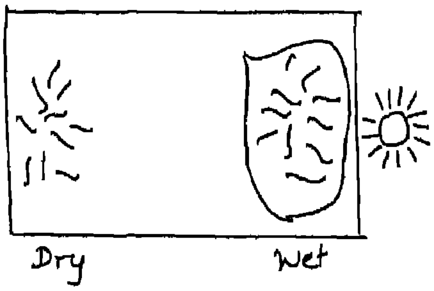

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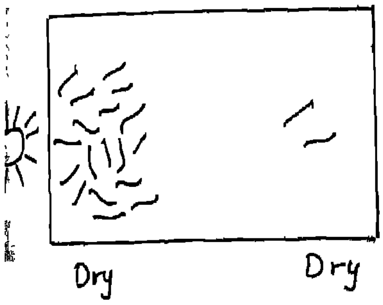

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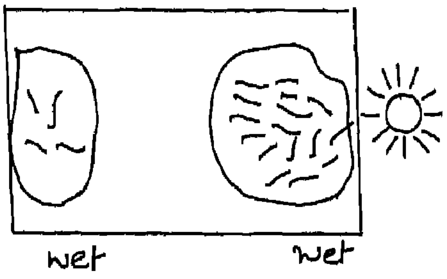

1. What do you conclude from diagram 1 and 3?

2. What do you conclude from diagram 2 and 4?

3. Is any other experiment necessary? If yes, suggest the experiment with diagram.

We have not taken into consideration pupil's capacity to process information. Pascual Leone has done some significant work in this area. This constraint is biologically determined and must be taken into account while undertaking studies on accelerated thinking. In other words, the demands of training should not exceed this capacity. The Piagetian explanation is in terms of lack (absence) of logical structure. However, unlike A.E. Lawson, we did familiarize our pupils with the concept of variables; and that too in a wider context. Still, the results on "The Exclusion of Variables" scheme of thought have been more or less the same in other cultures too. It then means that this scheme of thought is too lazy, laborious and difficult to promote among children below the age of 11 years. The type of school attended to hardly matters. On balance, it appeas that "stating hypotheses and Testing hypotheses" must be regarded as two separate and distinct variables for teaching purposes.

Piaget stresses self-activity (also applicable to teacher training) and self-experience which ultimatelylead to the development of logical thought in the self-education of the individual. It may not be inferred from above that Piaget hardly gives a significant rolee other than this to the teacher in the intellectual development of children: 'they also serve who stand and

.....39

On the other hand, Piaget gives a reflective role to the teacher in his scheme of things, he must try to find out what words mean to the children, he must design well-thought-out structured experiences so that they may continue learning even outside the classroom for months and months, he must provide opportunities for learning in a social setting, he must provide opportunities where children (even of different age groups, of course, not differing very widely) clarify each other's concepts through teaching and lastly find time to carry on conversations with them either individually or in small groups in order to find out their real thinking and feeling on difficulties and issues which agitate them (39). It appears that he does not take away whole of teacher's freedom but allows him to invervene. If he does not, no educational system in the world will tolerate even a couple of Summer Hills. (A.S. Neills) even for a couple of days !. However, any educational system worth its name will allow to some degree to its teachers the following eight steps of the helping processes based upon the combined views of E.H. Erickson, Jean Piaget and Robert R. Sears. This approach, if applied, will take us very close to the concept of Clinical Teaching.

HELPING PROCESS

Eight Steps of the Helping Process

1. Observing situation.

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2. Ordering and assessing observation.
3. Predicting course of development without intervention.
4. Predicting course of development with intervention.
5. Formulating tentative hypothesis and or
66. Purposeful intervention, including acknowledged noninterference.
7. Observing anew after intervention.
8. Reassessing the previous appraisal and formulating new hypothesis.

Sub-divisions of the Helping Process

Study Process	Appraisal process	Treatment Processes
Observation(1) x Ordering and assessing the observaations(2) Observing a new after intervention(7)	Predicting without interveention (3) Prediction with intervention (4) Formulation of a hypothesis (5) Reassessing the previous appraisal and formulation of new hypothesis ( )	Purposeful intervention(6)

Let us now conclude this section in the words of Flavell who has been the best publicity officer of Jean Piaget:

> .....One hardly thinks of him as the Dr. Spock of mental development. And yet it is our strong conviction that a thorough familiarity with his theory and data can be enormously helpful in the daily business of understanding and coping with children, whether in the role of parent teacher, nurse, or whatever. For one thing, the system provides a detailed

> normative frame of reference. If you have a rough idea of what children at a given developmental level are likely to be thinking about and how they are likely to be thinking about it; if youhave even crude guidelines as to cogitive possibilities and limitations, as to what the child can and cannot grasp, and how he will and will not be able to construe events, then you can better understand what the child has said and done, better predict what he will say and do next, and in general carry out your caretaker function with greater confidence and skill. But there is more to the adult child encounter than just caretaking per se more than just doing things with and to the child in order to achieve some short or long range socioalization goal. One may also want simply to climb inside his world to achieve a measure of emphatic understanding as well. He has told us enough about cognitive structure at different age levels to permit us to do a crude kind of computer simulation to "program" outselves to process information in rough approximation to the way the child processes it. This pursuit of the child's phenomenology comparison - with norms approach, be of real help in the child-rearing or care-taking enterprise. But it does not have to stand or fall on its pragmatic merits. There is a sense of satisfaction, a sense of doing something worth doing, just in achieving a degree of communion and sympathetic participation with a mind quite unlike one's own.

Lastly, the basic idea is to help children form scientific concepts which classiify and interpret their experiences. They can also apply these concepts to new situations. So there is something common between the pupils who are learning science and the scientists who are practising science. The common points are:

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(i) Both try hard to understand the world in which they live.

(ii) Both are curious to learn.

(iii) Both seek relationship in what they observe.

(iv) Both build up on what they know and modify their ideas by setting up hypotheses and testing them.

So the whole problem of accelerated thinking has to be seen within a certain ccontext. One such context relevant to our purpose is provided by the space (science processes and concept exploration project), a project currently in progress in England under the control of Professor P. Black and Wynne Harlen

THE FINAL VERSION

OF

HUMP EFFECT IN PROBLEM SOLVING

THE FINAL VERSION
OF
HUMP EFFECT IN PROBLEM SOLVING

All our dignity lies in thought. By thought we must elevate ourselves not by space and time which we cannot fill. Let us endeavour then to think well; therein lies in the principle of morality.

BLAISE PASCAL
(1623-1662)

The Final Version
of
Hump Effect in Problem Solving

Abstract

Problem solving takes place in stages which have been variously described in literature. It is admitted that understanding in problem solving increases with age. But, Piaget in his experimental studies on ldgical thinking, did not follow up the peculiar behaviour of pupil errors. It is related to their appearance, disappearance, reappearance and finally disappearance. Moreover, he also missed an interesting observation where the mean performance of pupils rose up, fell down and went up again with age. Professor J.S. Bruner and Professor Sidney Strauss termed this phenomenon of temporary nature as "Growth Error" and "U Curve Growth" respectively. The mirror image of the latter resembled the "hump" of camal too.

The above two observastions were examined at depth over a decade in out studies on ldgical thinking. Here a problem solving test comprising eight schemes of thought was administered individually and in a goup situation to a group of 200 pupils (B _ _ 100) of grades VII to XI. The errors were recorded and graphed in individual problem solving process. It has defied firm explanation but the educational implications arising out of this study have been pointed out.

Background
to
The Study

By its very nature the investigation of human thought right fom infancy to adult-hood is a complex venture. Its experimental investigation through the techniques of problem solving is of recent origin. Problem solving takes place as soon as the problem is percieved by the problem solver and is aimed at to reach the goal. The problem is supposed to be not only new and novel but also at the same time there is supposed to be no direct solution available to the problem solver at the time of its presentation. However, according to K. Duncar (1945) it is also assumed that the problem solver possesses the needed information for solving it. Problem solving as a technique of investigation has been utilized very widely in research studies pertaining to the diversified range of conceptual schemes of thought in the fields of genecral psychology and the newly emerging literature on science education. When search for clarity is made overall confusion results when problem solving is defined as "combining the essentials of two isolated experiences" Mainer (1930) or as "the integrated activity of perception, memory, recall, association, generalization and reconstruction of ideas" Welch (1972). Even when seen in its specific context problem solving ability is said to vary very widely, for eg. from the simple finding of exceptions" at end (Hazlett, 1930) to the formal reasoning of complex nature at the other end (Inhelder, 1960). These

is inherent difficulty in tackling problem solving successfully when problem solving situations used to evoke thinking are too diverse.

Noticing
the
Hump effect

In his main study, N. Vaidya (1975) found that adolescent pupils commit a large number of errors while engaged in problem solving. In this field experiment where the adolescent pupils drawn from grades VI to X were matched on age, I.Q. and socio-economic status (N_200, B _ G and in each grade B=G =20) it was seen that dominent errors among the errors (shared at least by 20 percent of the pupils) were found to increase with age/grade before their frequency in higher age groups finally fell. When such frequencies were plotted the resulting curve took the shape of the "hump of the camel". It is of interest to highlight this finding because whereas undserstanding increased with age, the individual errors contrary to expectations too appear to have suffered their ups and downs before finally declining with age. Why should it happen? Is it the case of an adolescent/playing with figures thoughtlessly or arbitrarily iin the hope of being favoured with good luck? Is it his case to respond to the varied test items in any manner he likes, regardless of consequences and meaning? Is it the casee of lack of seriousness on his part ? Is

it his case of being caught between the horns of a dilema and getting muck ? Is it the case of hot chase trying hard to choose in haphazard directions as if in the manner of closing in on the problem ? Does it illustrate that the mastery of a thought process is through a path: uphill, thorny and often erractic ? Or does the adolescent regress as if on an adventurous as well as pleasent Piagetian journey during which he is trying hard to educate out himself, thinking that the right path to concept development lies in flourishing on experimental failures or problem solving situation in which either understanding suffers a dip or errors a hump ? Alternatively is it a fact of rubbing his schemes of thought wrongly, especially when he has personal reservations about his self acquired knowledge in contrast to school learning which does not set right his firmly held self centred thoughts ? Lastly, is it the case that he chooses to be very romantic in his computations when confronted with a problem situation leading to a chaos ? These are some of the stray notions which strike while having encountered this elusive phenomenon in several contexts:

(i) When the answer to the test item is contained in the problem itself.

(ii) When the test item needs an arithmatical or algebraic symbol.

(iii) When the count is kept of total number of trials or errors on individual steps.

(iv) When the same step is suggested again after having undertaken other steps in the furtherance of solution, namely, resting points.

(v) Lastly, when the count is kept of total number of arbitrary as well as extraneous considerations brought into the problematic situation during poblem solving.

Additional Support from Literature

Interestingly enough, Piaget did talk of regression in thought but did not later on follow up this observation. Mehler and Bever (1967) also encountered this phenomena in their studies of conservation. According to them this is a "temporary phase" when this scheme is still under development. Possibly it is a case of reacquisition of the same scheme of thought. Later on S.Z. Dubek and G.B. Dyer studies longitudinally the Piagetian developmental stage and the concept of regression. 65 children ranging in age from 5 - 9 years constituted the study sample who were tested individually for three years. The tools comprised intelligence tests, personality questionnaire, Rorschach Inkblot test and a series of Piagetian tasks concerning space, conservation, causality and class inclusion. Eight true regressions were noted. The regression ranged from

5 percent to 1 perdcent under certain conditions. Interestingly enough, both Piaget scores and intelligence scores (wisc) favoured the regression of children.

Sidney Strauss (1982) reported similar work under the title U shaped behavioural growth on several problems relating to conservation take, Intensive quantity tasks, Direct function, Inverse function and proportions. These works which still are under development arose out of the work of Piaget, Werner and Vygotsky. They do not regard the shape of the curve as very importat and hence have tentatively named it as the "U shaped curve". It has 3 features namely (i) the behaviour appears (ii) it drops out at a later stage and (iii) it reappears normally again at a higher age group. N. Hall (1976) encountered the same phenomenon among doctors, nurses, wards and hospitals in the area of anxiety encountered with time as one of the dimensions. Let us now mention all such studies chronologically in the tabular form below:

Author	Year	Title
J. Meher and T.G. Bever	1967	Cognitive capacity of very young children.
S.F. Diggory [redacted]	1972	Cogitive process in Education: A Psychological Preparation for Teaching and curriculum development
N. Vaidya	1975	A Study of some aspectsof Thinking among science students of adolescent Age
J. Piaget and B. Inhelder	1977	Conservation of substance, weight and volume in the essential Piaget (Pg 356)

Author	Year	Title
Suzanne. C. Martorano	1977	Developmental Analysis of Performance on Piaget's Formal opefational tasks.
K. Lovel and E. Ogilive	1977	Conservation jof Substasnce Growth of conservation of volume.
David Elkind	1977	Children's Discovery of conservation In the Essential Piaget (Pg. 357)
T.S. Sandhu & N. Vaidya	1978	Hump Effect as observed during problem solving.
L. Kansakar	1979	A study on the Exclusion of variables during Adolescence.
Eryl. Rothwel Hughes and Joseph Rogers	1979	Conceptual Powers of children: R.M. Beard on (i) Conservation of weight (agerage ability: Pg.45) (ii) Conservation of weight (averaage ability: in-correct responses: Pg.61) (iii) Conservation of volume (average ability: Pg. 155)
T.S. Sandhu	1980	A factorial study of adolescent thought using Piaget type tasks
S.C. Arya	1981	A study of grwoth of scientific concepts among elementary school children.
Madhu Mathur	1981	A study of growth of experimental mind during adolescence.
Sidney Strauss	1982	Ancestral and Descendant Behaviuours: The case of U shaped behaviroal gwoth.
M.S. Padmini	1982	The growth of exclusion of variable during adolescence.
Sadhana Joshi	1984	Some aspects of logical thinking within Piagetian context among certain group of adolescent pupils
M.S. Bhati	1985	Hump Effect: An Exploratory study.

For further clarifications, this phenomenon was referred to Professor J.S. Bruner at Oxford in 1976. He commented on it as follows:

> The type of error that you refer to which we speak of as growth error, is one in which a growing child tries out a new strategy although it is not well developed and uses it in place of one which has been working well. It is error of this sort which suggest to me the venturesome of learning during this early period, the human beings are willing to shift to a less certain and more powerful strategy, before they have it under control, in preference to one which is safe, sound and dull.

The Presentation and Graphing of select data on Hump Effect

Let us now present some select data from studies where Hump effect has prominently apppeared, both during the process of acquisition as judged by the mean scores and the particular dominent error at least shared by 20 percent of the pupils. It is to be reiterated that Hump effect was not the specific object of investigation in any one of the below mentioned studies. It was interpreted when we found that a young child gave a correct response whereas the older one gave an incorrect one. Let us now have a look at the data along with their graphical representations.

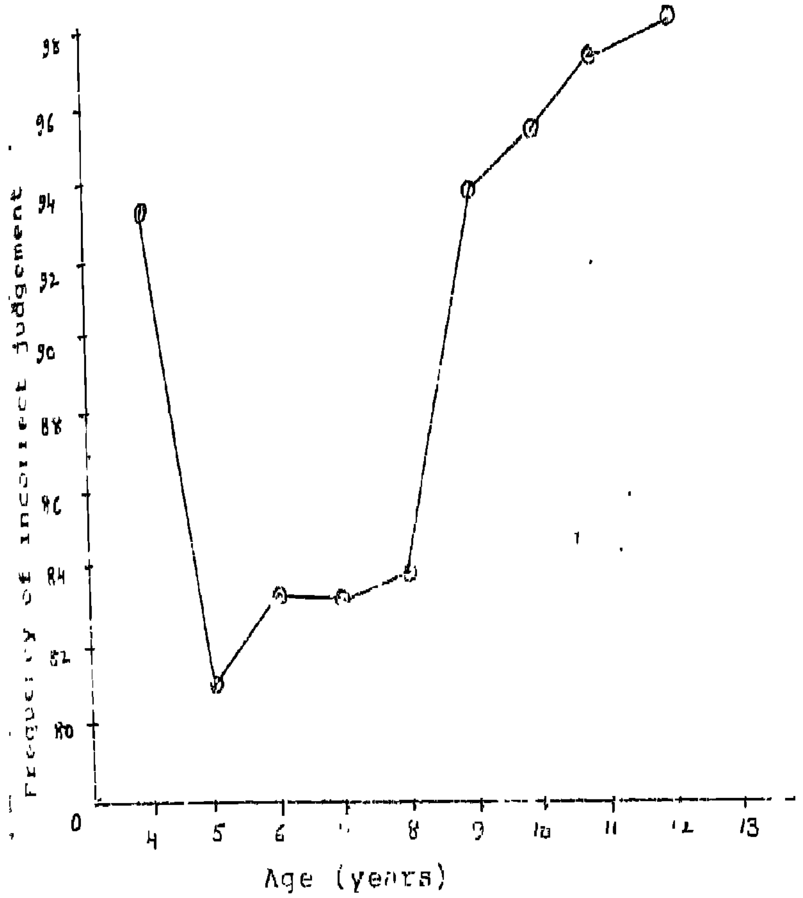

Fig. 2: Showing frequency of incorrect judgement on inverse function and proportions task at all age per socio-economic group.

Incorrect Judgements

Task	Solution	S.E. Group	Mean Age groups									
			4	5	6	7	8	9	10	11	12	13
Inverse function	-	Advantaged	91	81	83	83	84	94	95	97	98	-
Proportion	-	Dis-advantaged.	-	82	82	82	82	83	89	92	97	100

2. Mathu Mathur (1981)

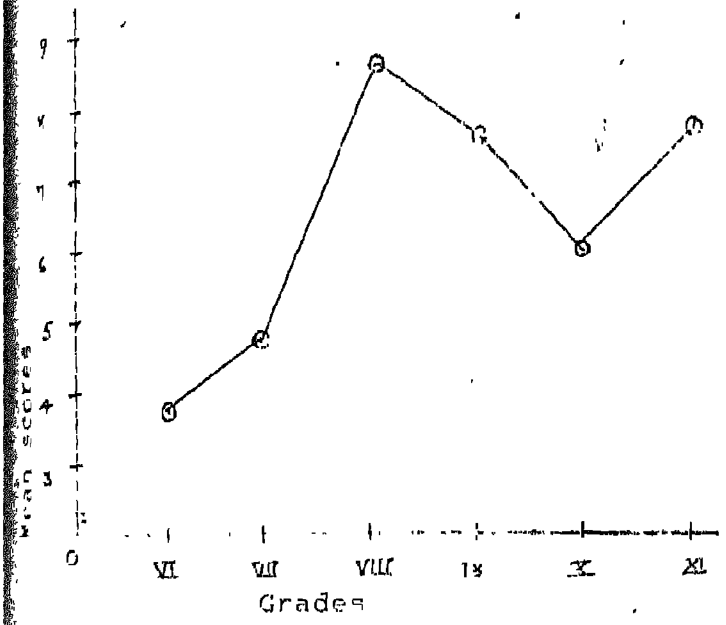

Fig. 3: showing mean scores at various ages and grades, both controlled.

	VI	VII	VIII	IX	X	XI
flow of water through a tube	3.8	4.5	8.1	7.8	6.2	7.8

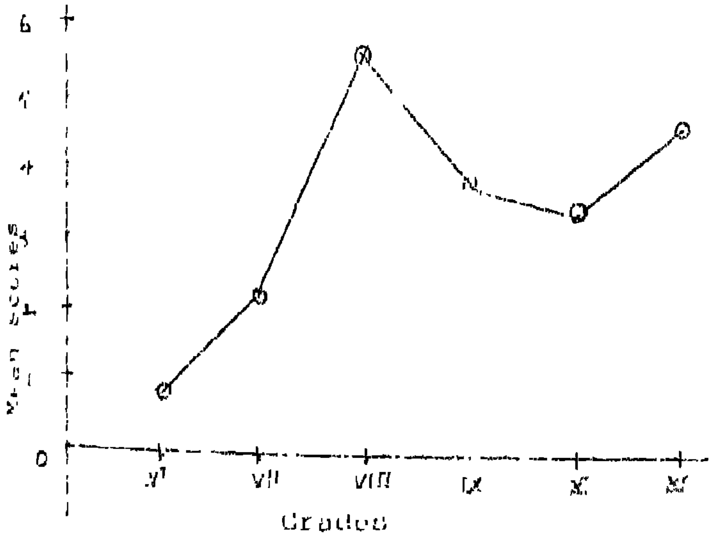

Fig. 4: showing mean scores at various ages and grades.

	VI	VII	VIII	IX	X	XI
Magic seed (resting points)	0.6	1.8	5.5	3.8	3.5	4.4

3. N. Vaidya and T.S. Sandhu (1978)

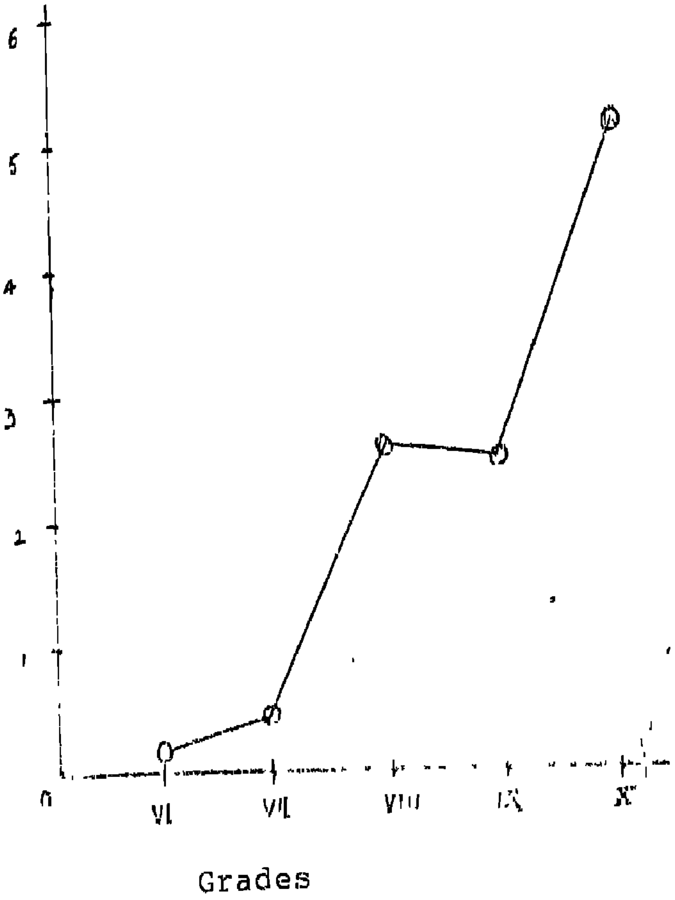

Fig. 5 showing mean scores at various grades.

	VI	VII	VIII	IX	X
nding the thick- ess of a fish math- matically when eal depth, apparent epth and depth of tank are given.	0.05	0.28	2.56	2.30	4.90

4. Piaget and Inhelder (1977)

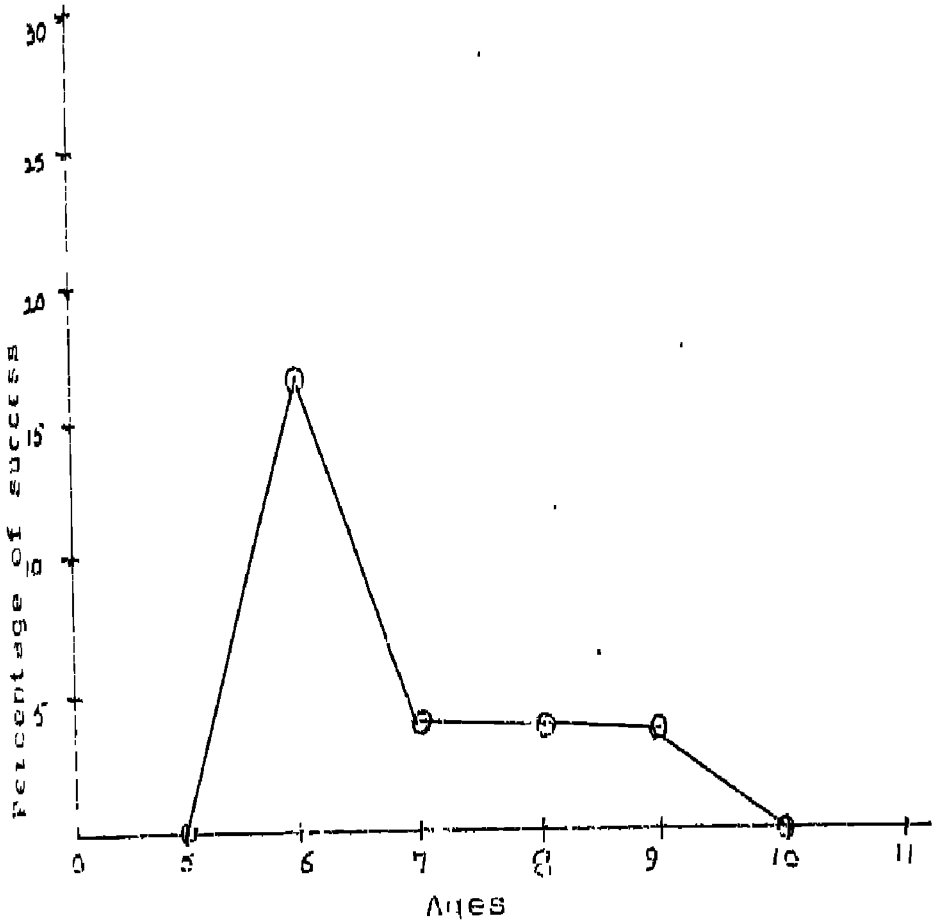

Fig. 6 showing frequencies at transitional level at various ages.

Ages	5	6	7	8	9	10	11
Conservation of substance	0	16	4	4	4	0	0

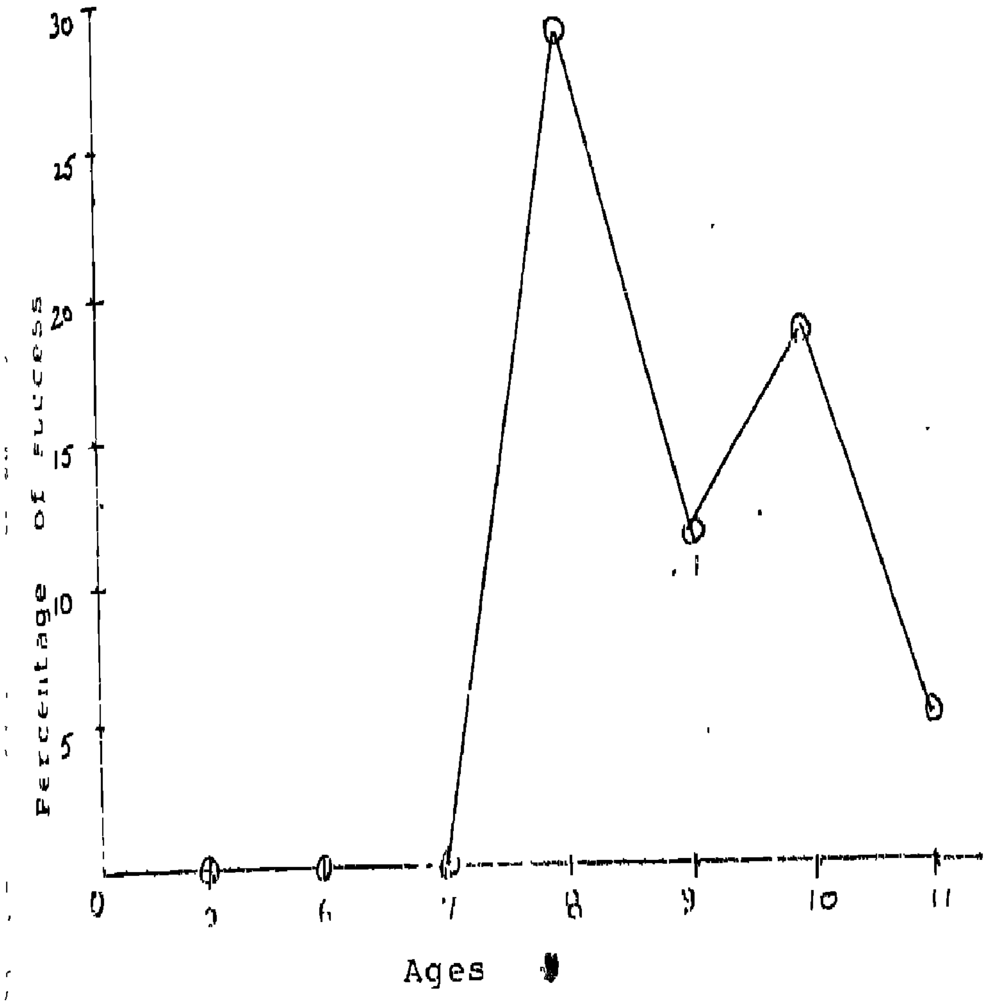

Fig. 8 showing frequencies at the transitional level at various ages.

Ages	5	6	7	8	9	10	11
Conservation of volume	0	0	0	28	12	20	4

5. N. Vaidya (1975)

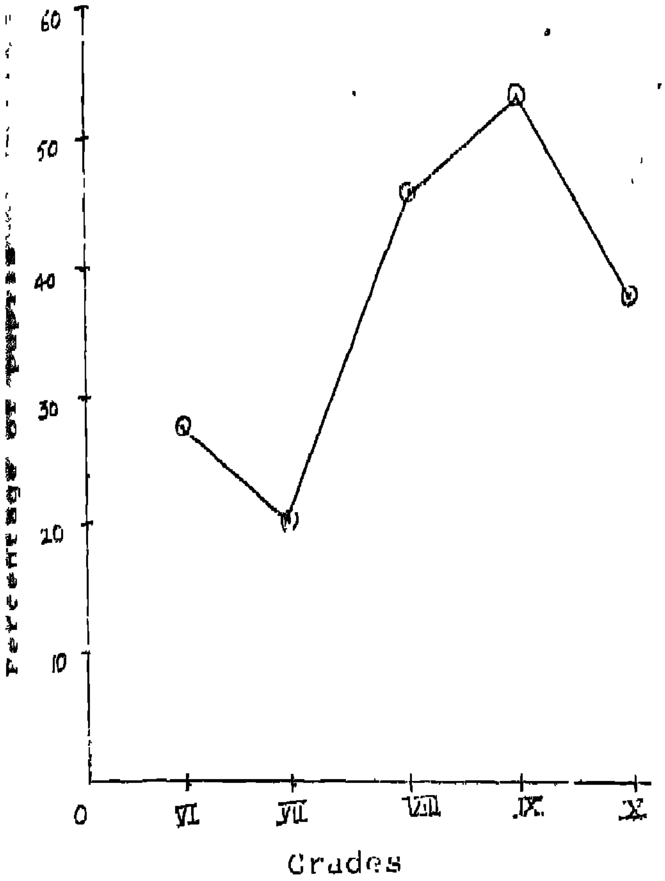

Fig. 9 showing the frequency of dominant error at various ages and grades (both controlled)

Grades	VI	VII	VIII	IX	X
Percentage of students sharing the dominant error to the question: suppose a donkey has two horns. How many horns in all have 8 donkeys ?	27.5	20	42.5	52.5	37.5

6. J. Mehler and T.G. Bever (1967)

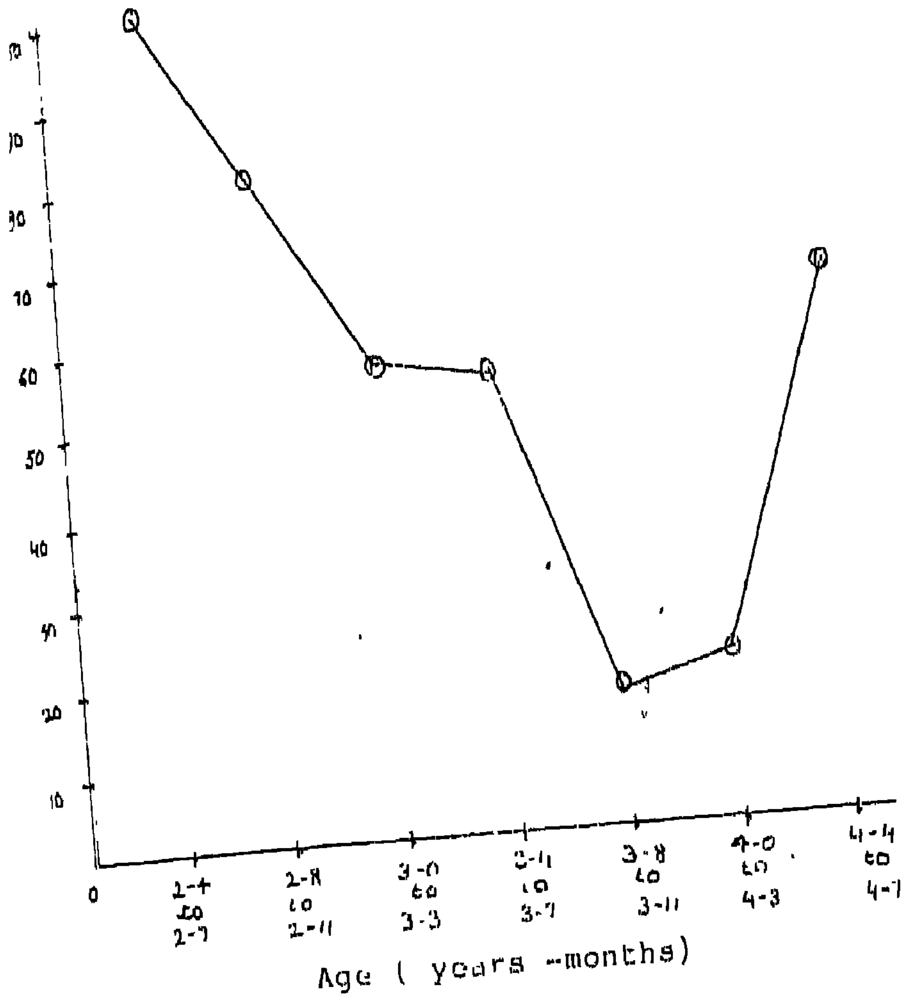

Fig. 10 showing the percentage of conservation at various ages.

Number of children tested in each group is as follows:

2-4 to 2-7	2-8 to 2-11	3-0 to 3-3	3-4 to 3-7	3-8 to 3-11	4-0 to 4-3	4-4 to4-7
22	29	30	36	13	22	26

Suggestions for further Research

The investigations of human thinking is a complex enterprise. When relevant findings become available method specialists and teachers are going to the major beneficiaries. " Teaching to think " according to Edward-De-Bono is one of the chief objectives of education. In his vast experience with teaching for thinking all over the English speaking work, he also saw the significance of Hump effect which again lacked any theoritical explanation. It is, thereefore, essential to seek a theoritical construct for clarifying this elusive phenomenon. One is not informed much when the world known teacher for thinking says "It may be necessary to go uphil for a while and face awkwardness and other difficulties before things settle down on the other side of the hump". In this context the following problems are suggested for further research:

(i) It needs a highly controlled factorial study on children over a wide age range and intelligence. Other outside variables which should not be ignored are: rural/urban divide, home-background, sex differences and personality factors. Moreover the past history of the individual cannot be ignored. It is only then the second phase of the hump effect can be made increasingly transparent.

(ii) It is necessary to carry out several intervention programmes for the development of accelerated learning.

he nature of the newly generated thinking process needs o be evaluated for relevance, permanence, stability and turistic growth.

iii) It is ideally speaking essential to carryout ongitudinal studies for the findings based on such tudies may provide a developmental view to the teaching-earning process.

iv) It is further suggested to develop additional chemes of thought for investigations. Examples are those f correlations, guessing, INRC structure, elaboration nd functional fixedness (rigidity in thought).

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10

Focus on Education : a developmental view

- Principles of Developmental Psychology
- Main views for Education from the developmental point of view.
- Models of Teaching
- Learning cycle and resoning patterns
- SOLO Taxonomy
- With objectives in mind
  (Science 5/13 Project)
- Teacher Training and Derivation of principles of teaching
- Accelerating the development of formal thinking
- Problem solving methods
- A problem solving model of instruction
- Learning with projects
- Another logical approach
- Attempting shadow studies
- Concept mapping and the cartography of cognition
- Concluding statement.

The heaven and all below them
Earth and her creatures,
All change,
And we part of creation
Also must suffer change.

— Ovid Meta Morphosis
(Translated)

The Principles
of
Developmental Psychology

Developmental Psychology :

Human behaviour is not only variable but also dynamic in its character. It is not a fixed entity but changes right from birth through middle age; and finally, to death. It has been studied intensively as well as extensively during infancy and childhood. So the term developmental psychology is interchangeably used with child psychology, adolescent psychology, adult psychology and genetic psychology. On close reflection, these terms are different from each other. Genetic psychology, for example, shows a concern for autogenetic as well as phylogenetic behaviour. The encyclopaedia dictionary of psychology defines it as the study of remarkable changes in behaviour which happen as people grow older. But what about development ? It has been seen differently in different theories.

The Concept of development
as
Seen in three different theories

S.No.	Nomenclature of the Theory	Basic notions
1.	The mechanical mirror theory	Man, essentially speaking is passive. Environment is responsible for what an individual becomes.
2.	The organic lamp theory	Man, essentially speaking, is active. His development is seen as a self constructive process.
3.	The psychoanalytic theory	Man is, basically speaking irrational and affective. It takes him time to control his impulses and passions. Still, he remains in a state conflict between instructs and moral restraints. Growth is a function of passions, instructs and external demands (1).

Principles of development :

The above mentioned views have, in turn, led to the emergence of certain principles of development which are listed below :

(i) All individuals differ from each other. In other words, no two individuals are expected to react in the same manner to the same environmental stimuli.

(ii) Development is a function of maturation (genetic effects operating in a self limited cycle) and learning. The latter is that aspect of development that comes through exercise and effect on the part of the individual.

(iii) Each species has its own characteristic pattern of development. Individual differences exist within each species but are ignored when one is looking for the general trend of development therein.

(iv) Each phase of development is characterized by its dominant set of traits. But all traits develop in their own way and at their own rate. Moreover, the development is marked by patterns of equilibrium, disequilibrium and again equilibrium at a higher level. It is during disequilibrium that children frequently show problem behaviours.

(v) The development is seen as cumulative where all sorts of incidents matter. For experiences, experiences go on collecting until they influence the rate of development.

(vi) The ideas and abilities of children change enormously between the ages of 5 & 13. Otherwise, the changes are gradual and continuous which are pictured as follows :

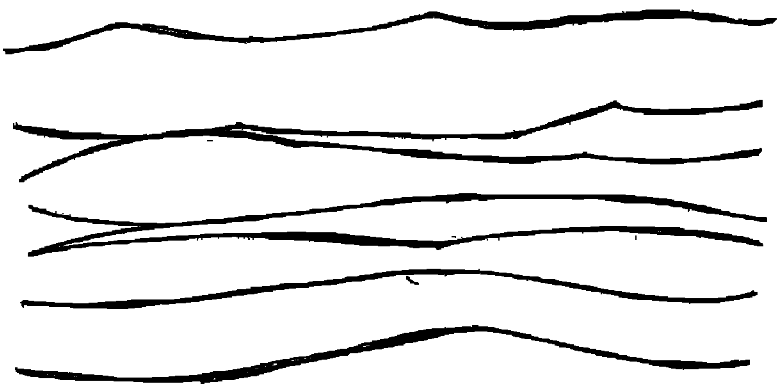


Fig. 1 It shows the wavering nature of the developing abilities

It is not out of place to mention here that the details of the strands of development vary from individual to individual. At the same time, Piaget has shown that it

is possible to discern a pattern in them which is similar for different individuals (2).

Five main views for Education from the development point of view

Let us now describe in brief the five main views of education from the developmental point of view which depend upon the natural abilities of the growing children. It is essential to place the child at the centre of education rather than the other way round. Thus the children learns to master the stimuli rather than the responses at the input level. Initially, it is a time consuming process but finally, the gains or immense because the child is able to help himself. He, thus, learns "how to learn"; and becomes an autonomous learner. There are other advantages too. First, children learn to work hard right upto the limits of their their physical enderance. Secondly, the knowledge thus gained by them is of lasting value. Finally, the teacher can attend to the needs of other children who need him. With this end in view, the following five main views for education from the developmental point of view are presented. These are :

(a) Models of teaching
(b) Learning cycle and reasoning pattern
(c) SOLO Taxonomy
(d) With objectives in mind
(e) Teacher training and derivation of principles of teaching.

(1) Models of Teaching

In "The Essential Piaget" both H.E. Gruber and J. Jacques-voneche have suggested four models of teaching. According to them, the origin of these models lies in Piaget's work. These models are as follows :

(a) **Taos** : The learner has the access to diverse curriculum materials and activities but he is under the overall control of the teacher. The goals - academic and social are achieved gradually. The learner is free to pursue his academic development. The model is characterised by both play and imitation among the learners.

(b) **Paris** : Learners feel spirited in disagreement. The atmosphere is such that ideas are exchanged through discussion. Such informal atmosphere should be present in the classroom so that a child can open up. The child in such a setup develops qualities of leadership, cooperation and persistence in the face of difficulty. He develops respect for authority too.

(c) Athens : Dialogues lead to solution of the problems. The underlying idea is to obtain clarity of the lazy concepts through a series of questions and answers. It stimulates thought, develops understanding, enhances problem solving skills and contributes to the stock of valuable knowledge.

(d) El-Dorado : This is a generalisation of the Athens model both qualitatively and quantitatively at a higher level. Teachers and students are both involved in play as well as imitation. The teacher has a directive role but shares his knowledge with children by living it (3).

(2) The learning cycle and Reasoning patterns

Robert Karplus, while working on the project "Science Curriculum Improvement Study" incorporated two complementary approaches, namely nature and structure of science; and recent findings in cognitive psychology. Exercises were introduced with focus on the development of logical thought. To achieve this objective two imaginative notions suggested are :-

(a) Learning Cycle :

The three types of lessons in the cycle are exploratory, invention and discovery. Exploration involves manipulation of the experimental objects. There is not much guidance from the teachers.

In "invention", the concept development relating to the learning situation takes place. In the discovery phase, children are expected to apply the concepts in different ways to the problematic situations.

(b) **Reasoning Patterns :**

Karplus identified 10 reasoning patterns as given below :

1. Conservative reasoning
2. Additive reasoning
3. Proportional reasoning
4. Functional reasoning
5. Propositional reasoning
6. Seperation & Control of variables
7. Probabilistic reasoning
8. Hypothetico reasoning
9. Interactional reasoning
10. Experimental reasoning.

The concept of reasoning pattern enables the teachers to organise their activities at both concrete level and formal level of mental development.

Self regulation is necessary for intellectual development and goes on all the time during the life span of the organism. He makes use of his perceptual and

motor patterns and also his past experiences. The earlier concepts and models of action get revised, stablized and radically altered to meet the unknown situations effectively. The organism therefore survives because of self-regulation (4).

(3) SOLO Taxonomy :

It is said that Piaget had little to say on education. Here J.B. Biggs and K.F. Collis gave the piagetian stages of mental development, an educational orientation and enables teachers to determine the intensive and extensive nature of pupil responses on a rating scale. The development of enriched and remedial programme is then not far away. The rephrased Piagetian stages are then as follows :-

(a) Preoperational :

A response based on lack of comprehension, tautology, irrelevant association or denial of the data.

(b) Early concrete :

One relevant point is seen but others are missed.

(c) Middle concrete :

Several relevant points are noted but in isolation.

(d) Concrete generalisation :

The relevant dimensions of the data are perceived with their inter-relationships.

(e) Formal :

A superordinate, abstract principle is brought in, to enable valid generalisations from the given, with extensions to novel data. There is reluctance to close on a unique answer.

In their efforts to come close to the classroom situations, in their frameworks, they focussed on the highly varied structures of student learning outcomes. They, of course, found a lot of repetitions in their responses. Still, these responses, according to the authors were characterized by beauty, deftness, elegance and surprise. Being a speculative enterprise, they gave it a name of SOLO TAXONOMY, that is, the Structure of Observed Learning outcomes(5) To concretize it further, it is a task specific tool where any reasoning pattern of pupils is rated on a five-point scale. These levels in their Solo Taxonomy are : (i) pre-structural, (ii) uni-structural, (iii) multi-structural, (iv) relational, and (v) extended abstract. Their point of view is illustrated by asking the following question after the lesson on rain was given. Why is the side of a mountain that faces the coast usually wetter than the side facing the interior ?

(4) With Objectives in mind, Science 5/13 Project :

It is a collaborative project sponsored by the schools council, the Nuffield foundation and the Scottish

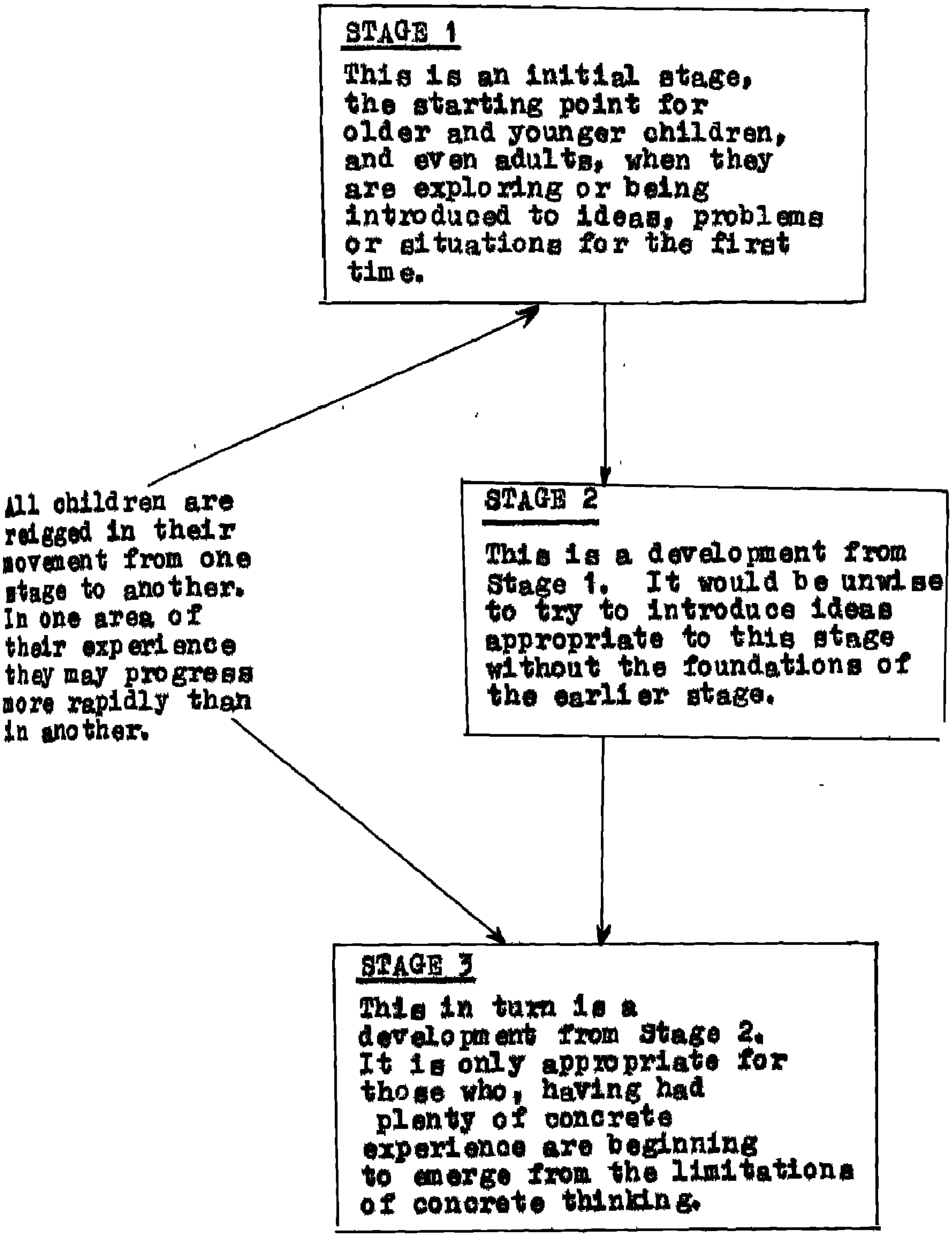
Education Department. It was housed at the school of education, University of Bristal, Bristal. The chief aim of this project is to help children through their teachers in learning science through first hand experiences, using a variety of activities, resources and methods. They have produced several units of work which can be tried elsewhere too. Examples are those of "Working with wood, early experiences; Science from toys; structures and forces; mini beasts, metals, plastics, roles, gaps any activities, and the like and unlike". The project team raised the following three questions to be answered.

(i) What Science ought to mean to children ?

(ii) What objectives do we intend to achieve through learning about Science ?

(iii) What workable measures can we adopt to achieve the objectives ?

The project is planned within the Piagetian frame-work. The teachers themselves carry out these activities first before they present these activities to children as teaching learning situations. Science teaching ceases to be factual only. Its scope is extended to the acquisition of skills, interests and attitudes. In other words, they learn to practise "Science" at a very young age.



STAGE 1

This is an initial stage, the starting point for older and younger children, and even adults, when they are exploring or being introduced to ideas, problems or situations for the first time.

STAGE 2

This is a development from Stage 1. It would be unwise to try to introduce ideas appropriate to this stage without the foundations of the earlier stage.

STAGE 3

This in turn is a development from Stage 2. It is only appropriate for those who, having had plenty of concrete experience are beginning to emerge from the limitations of concrete thinking.

All children are reigged in their movement from one stage to another. In one area of their experience they may progress more rapidly than in another.

Fig.2 It shows the stage-wise presentation of teaching learning experiences

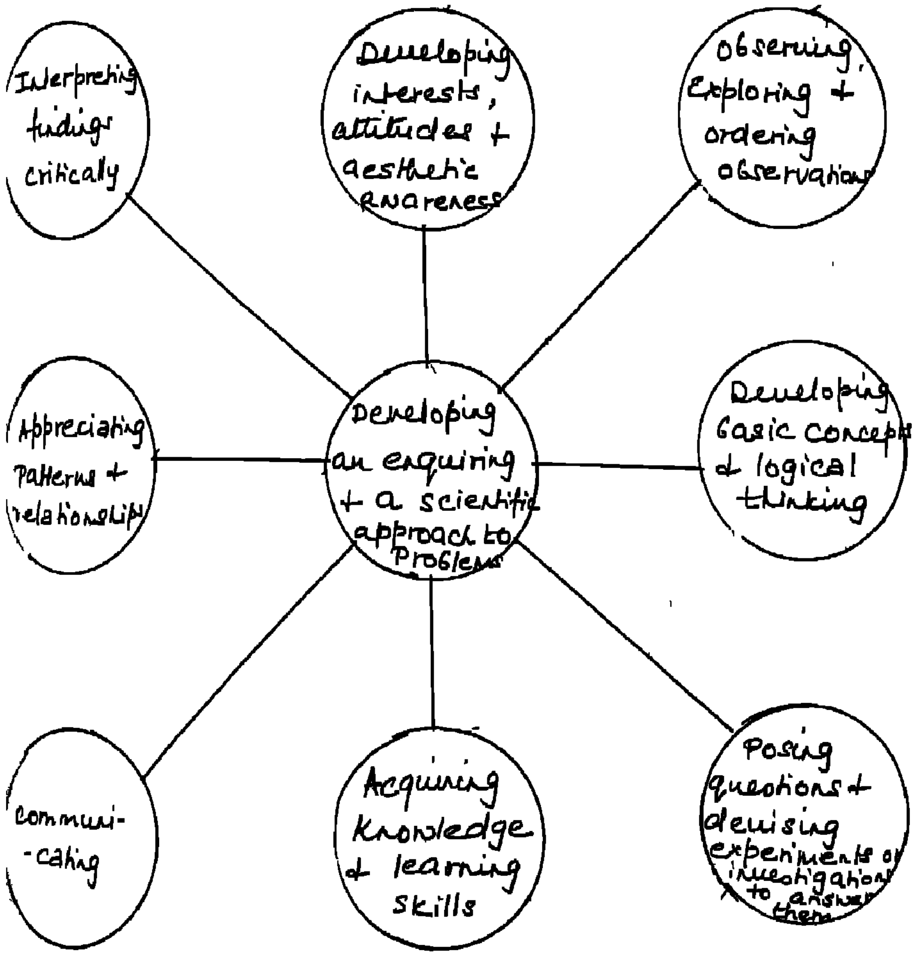

Interpreting findings critically
Developing interests, attitudes + aesthetic awareness
observing, Exploring + ordering observations
Appreciating patterns + relationships
Developing an enquiring + a scientific approach to Problems
Developing basic concepts + logical thinking
communi-cating
Acquiring knowledge + learning skills
Posing questions + devising experiments or investigations to answer them

Fig. 3 It shows the various aspects of learning science for the development of scientific attitudes.

Certain awkward questions remain to be answered. Some of these are :

(i) What is the structure of a given stage or sub-stage in terms of abilities, skills, interests and attitudes ? It refers to a developed stage. If so, can its parameters be specified ?

(ii) How much as well as how far a given aim, say, a general aim is concretized in actual practice ? It does raise the issue of objective assessment too.

(iii) Is it possible to know the differences between two sets of children who have an inquiring mind and do not have an inquiring mind (6).

These in a way are philosophical questions which can be raised relevantly for any project.

(5) Teacher Training and Derivation of principles of Teaching :

Vaidya defined the Piagetian scheme of thought in educational rather than developmental context. Several such schemes of thought were defined (i) using summation, (ii) using constant difference, (iii) using proportion, (iv) using insight, (v) testing hypothesis, (vi) fomulating questions, (vii) proposing tests, (viii) using probability. The teacher poses a problem and encourages pupils to emit all sorts of answers. He provides hints and cues but is careful not to supply the answers. Pupils are free to work

over the problems for quite some time. Errors arising as a consequence of failure of acquisition of their schemes of thought also received his attention. The errors, according to him, are clues to understanding the nature of thinking processes, scientific constructs and concepts.

Jean Piaget's work had an important effect on teacher training techniques, these being :

i) remarkable reduction in lecture work
ii) encouraging small groups to work together
iii) providing opportunities for development of skills such as problem solving, communication, workshop and drawing
iv) individual attention and feedback
v) experimental outlook.

Vaidya also initiated a major project "The determination and development of Schemes of thought in Science during adolescence" (ERIC, NCERT). He then laid the foundation for the following principles of teaching.

(i) Begin where children are by providing them with physical objects to act on.

(ii) Allow children to study, manipulate, assess and describe gradually in conformity with their mental development.

(iii) Continue introducing appropriate and interesting activities and experiments based on pupil questions, problems and goals where teacher's view is one among several views worth exploring.

(iv) Train them to suspend data if they so warrant.

(v) Encourage pupil to pupil interaction.

(vi) Avoid technical terminology as far as possible.

(vii) Stress, spiral learning within the context of spiral curriculum.

(viii) Integrate all focal aspects of knowledge.

On the whole it can be said that pupils should be encouraged to work on their own (7).

Accelerating the development of formal thinking

Philip Adey and Michael Shayer (1990), both experts of long standing in Piagetian psychology, have investigated the acceleration of the development of, formal thinking in middle and high school students in a country wide project called Cognitive Acceleration through Science Education (CASE). In a way, there is nothing new about such studies. For example, Siegler, Liebert and Liebert (1973) found that even 10 year old pupils could be trained to solve the well known simple pendulum problem. They could thus form and test hypotheses. It was a case of direct training on the problem with hardly any attempt to test for its generalisation to other content areas and schemes of thought. Let it be understood that such gains are superficial. Even a young child could be trained to switch on or off the television set with the help of a remote control device. The real problem for him only arises when either the main switch of the house is off or there is no current supply available at that moment. In other words, it means that what is important is the play of variables either in isolation or in combination in a problematic situation. Such a line of attack has been adopted by Kurn and Angelev, and Rosenthal in their studies where pupils are introduced to the notion of measurement, as well as dimensions. They are also directed to have a look at conflicting perceptual situations with a view to understand and master them. Attaining the specific

solution of the problem is of secondary importance. Let us now return to the CASE project.

The project was carried out in day to day setting of the school itself. Control groups were also set up to measure gains as a result of interventions made which were as many as 30 in number. The project staff and teachers produced intervention lessons on 10 formal operational scheme drawn contextually from physics, Chemistry and biology. It was kept in mind that not more than 25 per cent of the usual time meant for science teaching will be given to the experimental classes. This in a way kept intact the school routine. There was, however, another spin off advantage of this project. The project teachers could became more sensitive to the sources of pupil difficulties in varied learnings and thereby develop certain strategies for overcoming them for the benefit of their pupils. The schools for this study were drawn from seven different areas in England, for example, inner city, sub-urban and rural schools. All the schools were co-educational. Age range covered was from nine years to eighteen years.

Let us now refer to the nature of interventions. The intervention lessons, each of 60 minutes to 80 minutes duration, incorporated formal operational schemes of thought, such as exclusion of variables ratio and proportionality equilibrium, compensation, combinatorial thinking (grouping), correlation, probability compound variables and conservation involving formal modelling. Initially, each intervention

lesson focussed on one scheme of thought. As the project progressed, the pupils were familiarized or led to see for themselves the naming of the variables, value of variables and the relations among them. It should not be lost sight of that pupils were given such problems which require the use of formal reasoning in that solution. There was no attempt to teach the rules of the game. Instead the pupil is expected to construct and use his own scheme of thought for solving the practical problem. This, in a way, is the beauty of the project. However, the findings of this project are hot clear-cut. The experimental group gained in levels of cognitive development, statistically speaking, than the control group. More specifically, it amounted to 2-3 months differential in development over a period of 2 years. It means, in other words, that this much extra effort is not worth it. The same is the case with enhanced achievement in science, a case of more or less dismal failure. The age/gender interaction as seen from the data is also found to be puzzling. At the same time, evidence suggests that the interventions for the development of accelerated thinking favours boys in the age group 11 years to 13 years.

Lastly, the Piagetian schemes of thought are not easily amendable to influence, "Nature first creates the material before it gives it a form", echood J.J. Rousseau in the 17th Century. It is true that the current teaching routines do not alter the rate of intellectual development.

But a gain of 23 percentile points obtained in 20 months in the case of experimental classes suggests that the number of pupils showing formal thinking doubles for success in traditional school science and mathematics. To put in other words, it ought to be the main objective of school to "alter cognitive development rather than to adapt instructing to existing norms". However, for achieving substantial gains in cognitive growth, a long term project as part of in-service education is urgently required (8).

Problem Solving Methods :

It is possible to simulate human behaviour. It is possible for computers to play chess. It is also possible to arrive at decisions by computers and evaluate the same. The term "Artificial intelligence" was applied to some such efforts. A problem solver has to see through the task environment and represent the same for his own benefit in his own ways. He then becomes transformed from task environment to problem space after doing considerable work simulated thinking. Simon and Newell have suggested quite a few problem solving methods which can be used both by human and computers. These are :

(i) Trial and error
(ii) Hill climbing
(iii) Means and analysis
(iv) Subgoals and working backwards.

(i) Trial & Error Methods :

In a way, these are the weakest methods. The methods have a place in problem solving especially when, with the unknown problem, one makes varied responses which, if recorded, can be evaluated. Trial and error effort is not, really speaking, blind in characters. If probed further, it turns out to be a trial and success effort by evaluating the various possibilities in the direction of the solution, for example, trying the various keys for opening a lock.

(ii) Hill Climbing Method :

Metamorphically speaking, it means reaching the top of the hill. Your view of the Scenario or the problematic situation changes as you go up the hill or, say, down the till too. Once you are up, it differs from trial and error method in the sense that you are sure of the first step you take whether you are going up or down. At the next step, you can change your strategy and so on. This technique is used by physicians for determining the does for a patient suffering from a chronic disease. They start with a low dose and go on increasing it in the light of new symptoms or the other way round. It may as well happen that he may start with a minimum dose, increase it to obtain a curve until the patient gets worse. He still gets cured. Thus, we can adjust the dose to suit the patient's disease or he may be

given a high dose initially and wait for 2-3 days to see its effects. He may repeat the same dose in a decreasing manner at different intervals of time. In sum, one reaches the needed point which may not really be the summit of the hill.

(iii) Means End Analysis :

It is a bit more advanced than the first two mentioned above. It was the main method of problem solving incorporated in the well known Computer Programme namely "logic theorist" and "General problem solvers". The former programme could tackle problems posed in symbolic logic and the cater those problems which could be represented formally in terms of problem space using means-end analysis. To illustrate,

These are the two problems :

a) $\frac{10}{20} = \frac{x - 5}{x + 5}$ (Cross multiply/simplify 10/20 which is equal to 1/2 and then cross multiply)

b) $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ Where $v = 10$ cm
$u = 50$ cm

This problem can be done in the following ways :

$\frac{u + v}{uv} = \frac{1}{f}$ if $f = \frac{uv}{u+v}$ substitute values of u and v

Or substitute values of u and v

$$\frac{1}{10} + \frac{1}{50} = \frac{1}{f}$$

$$.1 + .02 = \frac{1}{f}$$

$$.12 = \frac{1}{f} \therefore f = \frac{1}{.12} \times 100 = 8.37$$

Programming can provide rule which is simple and quick. All the three metods constitute a sequence. The problem solver must have of course background knowledge to solve the problem. Only the use of that knowledge in new ways leads to solution of the problem (9).

(iv) Subgoals and working backwards :

Let us see one of the variants of this last mentioned strategy, that is, subgoals and working backward. It is trying to solve the problem from the end to the givens. In the well known Dancer's tumour, if it is the subgoal to weaken the rays (radiations), the problem then is how to accomplish it. So another subgoal is set up to achieve this objective. So far Duncer, search for partial solutions is retrospect possesses the character of a solution and that of a problem in prospect. When such efforts are summed up without evaluation in the first instance, these constitute the extent of thought brought into the problematic situation. Let us now end this discussion with a classic toy puzzle where hill climbing, one of the problem solving strategies fails completely. Let us then try to use the means-ends analysis.

Learning with Projects :

There is an interesting project going on at the Mirambika, Mothers International School, New Delhi. It is based on Free Progress which Mother has defined as

"Education guided by the sould and not by preconceived ideas". The younger children receive most of their education through project work. It is approached intuitively as well as analytically and systematically. The following three principles of teaching express the philosophy of school at the Merinbike. These are :

(i) Nothing can taught. Teacher is not a hard task master but a helper and guide. He does not train pupil's mind but shows him how to perfect his instruments of knowledge.

(ii) Mind has to be consulted in its own growth. It is he himself who must be induced to expand in accordance with his own nature. Everyone has something divine, something his own, a chance of perfection and strength in however small a sphere which God offers him to take or refuse. The task is to find it, develop and use it.

(iii) Education is to work from the near to the far, from that which is to that which shall be.

Let children react to what they read. Let them express as freely as they can. Two eight year old girls : Chiya and Mira were working on the topic of air. They incidently learn that fishes also need air. How can fishes breathe was their dilemma. So they chose the topic "FISH".

Underwater Yoga

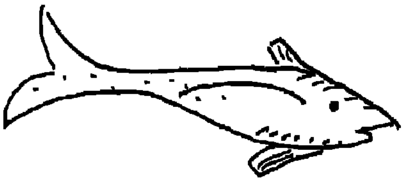
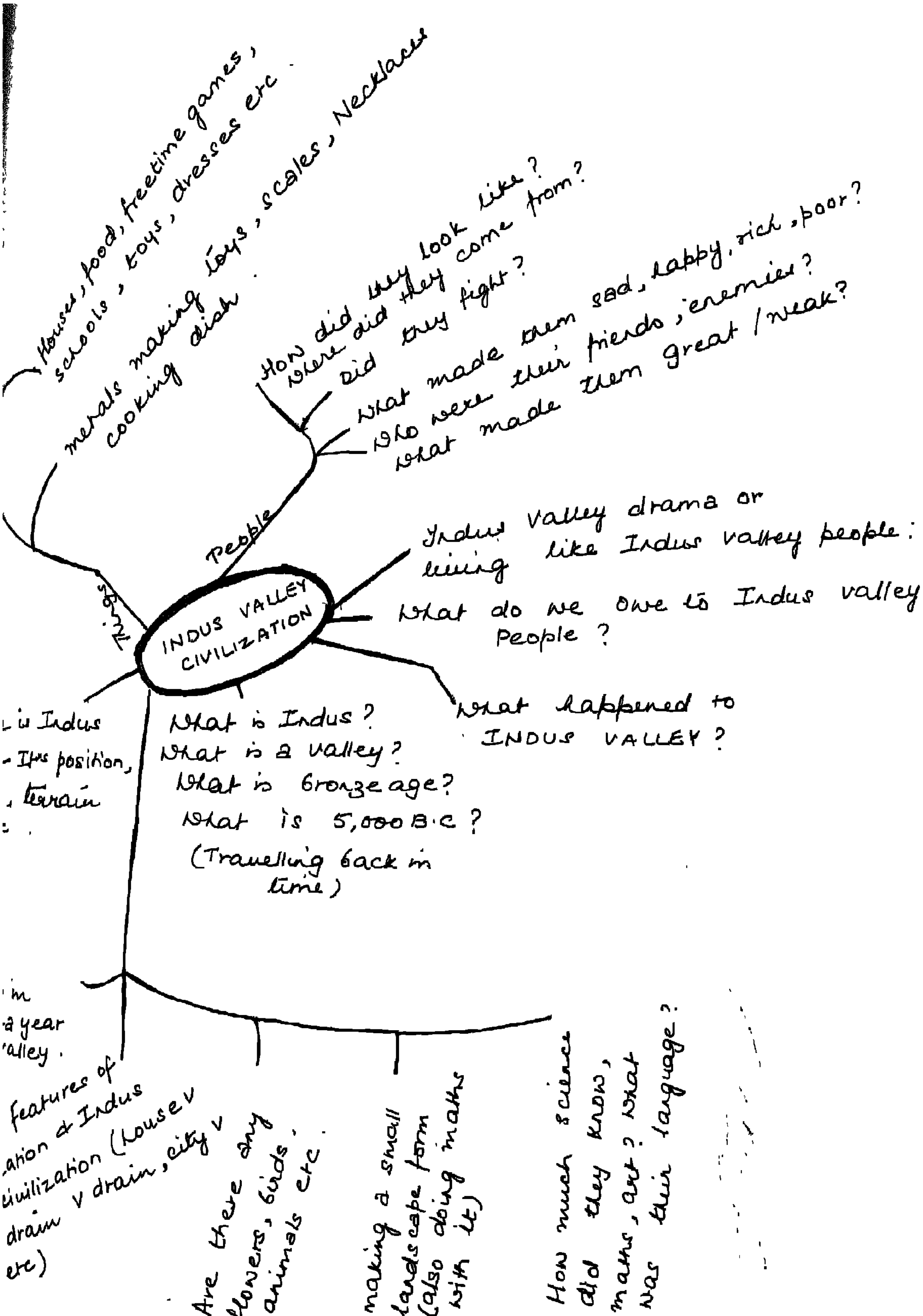


Fig. 5 It shows the figure of the fish as drawn by one of the pupils.

The fish stands on its head the whole day catching works, while doing that it also does yoga because it stands on its head.

It is a starting point. Further progress takes place when the effort is made to find out for days. In their case, the learning process comprises: information, assimilation and utilisation. Let us consider another illustration where eight year olds formulate their own bonafide questions, a sort of brainstorming at the start of the Indus Valley Project.


INDUS VALLEY CIVILIZATION
Houses, food, freetime games, schools, toys, dresses etc.
metals making toys, scales, Necklaces
cooking dish.
People
How did they look like?
Where did they come from?
Did they fight?
What made them sad, happy, rich, poor?
Who were their friends, enemies?
What made them great / weak?
Things
Indus valley drama or living like Indus valley people:
What do we owe to Indus valley people ?
What happened to INDUS VALLEY ?
What is Indus ?
What is a valley?
What is bronze age?
What is 5,000 B.C ?
(Travelling back in time)
is Indus
- Its position,
, terrain
'm
a year
valley .
features of
ation of Indus
civilization (house v
drain v drain, city v
etc)
Are there any flowers, birds, animals etc.
making a small landscape form (also doing maths with it)
How much science did they know, maths, art? What was their language?

g. 6: A brain storm at the beginning of the Indus Valley Project: Eight years olds formulate their questions

The soul of the Mirambika experiment is worth experiencing for it is an endless transforming experience. To any outsider, it appears to be a mad house in the absence of any planning, time table, documentation of activities and the usual paper work. To counteract this impression, a reasonable integrated information system exists which reflects not only the happiness of the pupils but those of teachers too (11).

Another Logical Effort :

Miss Phool Kaul investigated space concept as well as mental imagery and achievement in geometry, precisely speaking, polygons among the middle and secondary grade pupils of English medium schools in her research finding but to the approach of the study which if employed may enhance not only logical thinking but also achievement, say, in mathematics. She constructed several tests such as topoligical space, projective space, euclidean space, anticipatory transformation of modifications, elements of polygon, properties of polygon, rations between polygons and menstration and construction of polygons. Let us consider a few test items from the various tests prepared by the author.

(1) The topological space test -

The following is a set of four figures given as A, B, C & D. Out of which three are alike and one is not.

You have to identify that figure and write down its serial alphabet on the answer sheet.

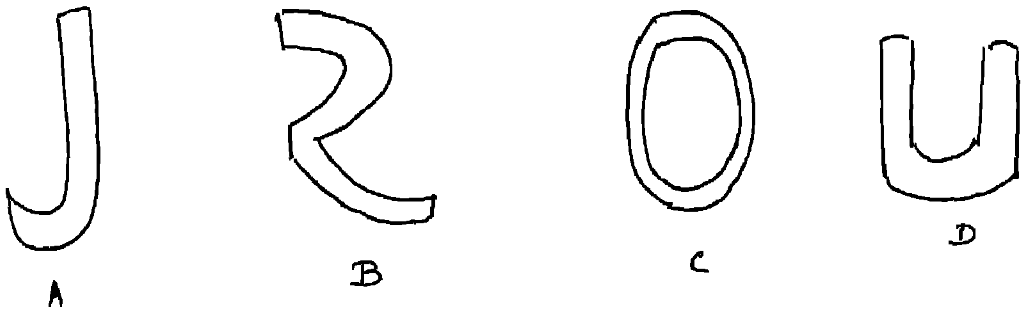


Fig. 7

(2) The projective/space test :

In the figure given below a flower pot is kept at 'P' in front of lighted lamp. If the flower pot it shifted to position 'Q' that is nearer to the screen, will the shadow of the flower pot on the screen be :

A) Smaller that its shadow at position 'P'.

B) Same as its shadow at position 'P'.

C) Larger than its shadow at position 'P'.

D) There will be no shadow on the screen.

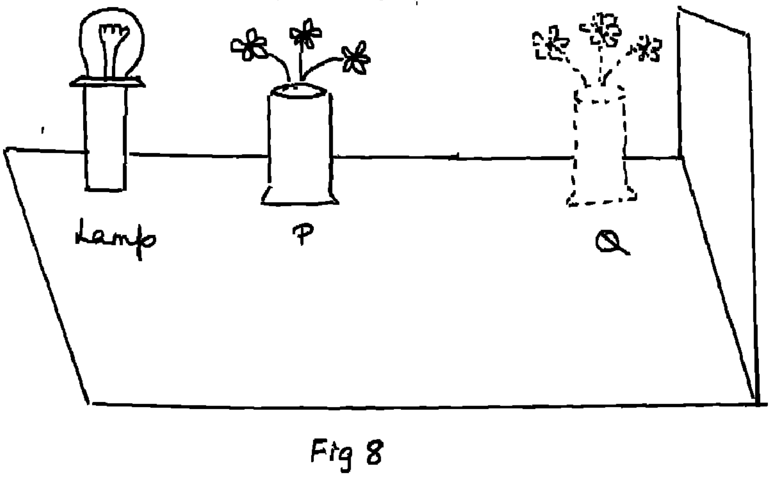
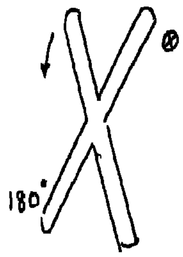


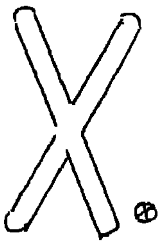
Fig 8

(3) Kinetic anticipation of product :

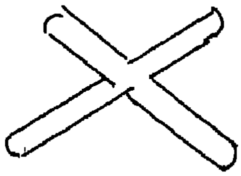
Select one of four figure which results when the problem figure on the left is rotated through 180°.

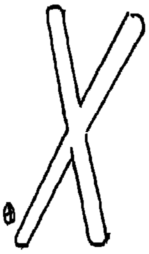


A

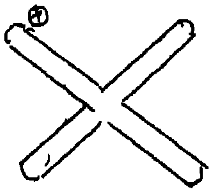


B





C

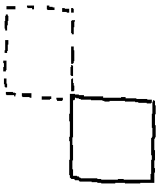


D

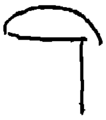
Fig. 9

(4) Kinetic anticipation of modifications

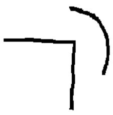
Select one of the answer figures which shows the fath traced when the square with dot is rotated in the direction shown to fit into the dotted figure.



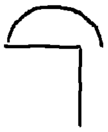
A



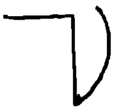
B



C



D



There are several other test items of interest. The teacher should administer such self-made items to his students in the class. He should record the frequences of wrong answers and try to discern a pattern of errors. It is this pattern of errors which should be tackled through demonstration experimentation and other individual activities. Here the students is being helped to see the relevance of his answer within the context of the question raised. He can also draw flow diagrams for highlighting any conceptual distinctions. Such efforts make the subject matter active, for example, use of active verbs, followed by response patterns of pupils. Thus all cognitive learnings, according to Professor Sullivan, get covered without much fuss or confusion (12).

(6) Attempting shadow studies :

Except the dreaded school inspections of the past in this country and elsewhere, the systematic observation of teachers' behaviour in his own classroom is of recent origin. The purpose of this exercise is to modify the behaviour of teachers towards the desirable educational ends. Such studies which were very popular over the last twenty years or so are now on the decline. The underlying teaching techniques were those of interaction analysis, micro-teaching, behaviour inventory and simulated teaching. Let the cobbler mend his own shoes. If so, it becomes a shadow study where the teacher worries about his various activities in his own classroom such as :

(i) How to teach difficult concepts to the noisy children.

(ii) How to control copying, mass copying and cheating during examinations?

(iii) How to determine the characteristics of learners ?

(iv) The detection of difficulties as these arise during the course of teaching.

(v) Judging the appropriateness of the content.

(vi) How to handle pupil capacities for transfering functional knowledge and skills across the curriculum ?

It is more than action research. One has to learn to improve oneself on one's shoe-string. Only two conditions are necessary. First, he should have a helpful or confident colleague who could either observes or participate in the very teaching learning process as a substitute teacher. Thus, he is freed from actual teaching for observing what concerned him most in the course of his work. Since he examines anything he deems it fit, the consequent constraints are quite manageable. To illustrate, he can study concerns relating to langage interaction among his pupils and teachers too in his own local setting, motivational activities and use of instructional and illustrative materials. Secondly, he can analyse his observations, data and interpret the same under his local conditions through recognised research techniques such as time sampling, deviation, frequency counting and non-parametric statistices. Pupil ceases to be a mere roll number at school because the teacher sees himself in relation to the demands made on him by the curriculum. What about the pupil ? Is he really motivated to learn at school under threat of failure in the name of maintenance of educational standards ? How to

give him a second chance ? The answer is to examine particular cases under particular circumstances at the cost of generality. The shadow study, therefore, blesses the teacher directly and the pupils indirectly(13).

Concept Mapping and the Cartography of Cognition :

The frame-work of thoughts as propounded by Gestalt psychologists, Germans and the Vygotskians were highly exciting enterprises. Whereas the frameworks were reflected upon, the basic ideas underlying them from the educational point of view were partially developed. It is given to human mind naturally to react, observe, analyse and synthesise observations and, nay, to apply knowledge and reason out things. At the same time, it also places restrictions on itself on its own thinking. So a group comprising Ausebel, Nanak and Gowin did creditable work on meaningful learning for the entrise period of schooling. It was A sort of meta learning strategy. To illustrate :

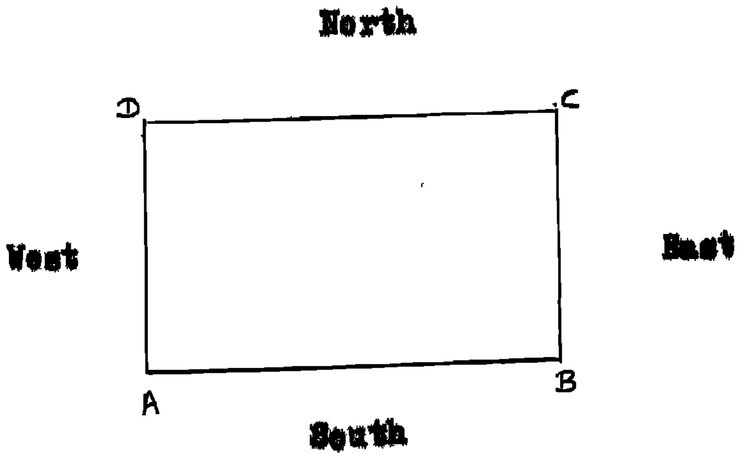


Fig. 12

Suppose a child walks from the point A 25 meters to the east, then 20 meters to the north, 25 meters to the west and 20 meters to the south. What is the distance between the starting point and the last point reached ?

When this question is posed to the young children, they fail to answer it. The simply sum up the distances. This simple example shows us to have a close look and scrutiny of their work on mapping and cartography of cognition. So mapping can be defined as representing a "set of meanings" under development. It runs parallel to the cognitive development. If so, it provides a psychological structure to the teaching of any school subject. So naturally, it is related to communication, growth and reflection of knowledge and development of understanding. In sum, a cognitive map possesses immense summative, integrative and generative power, using tools such as concept circles, concept maps and "V" diagrams which are shown below :

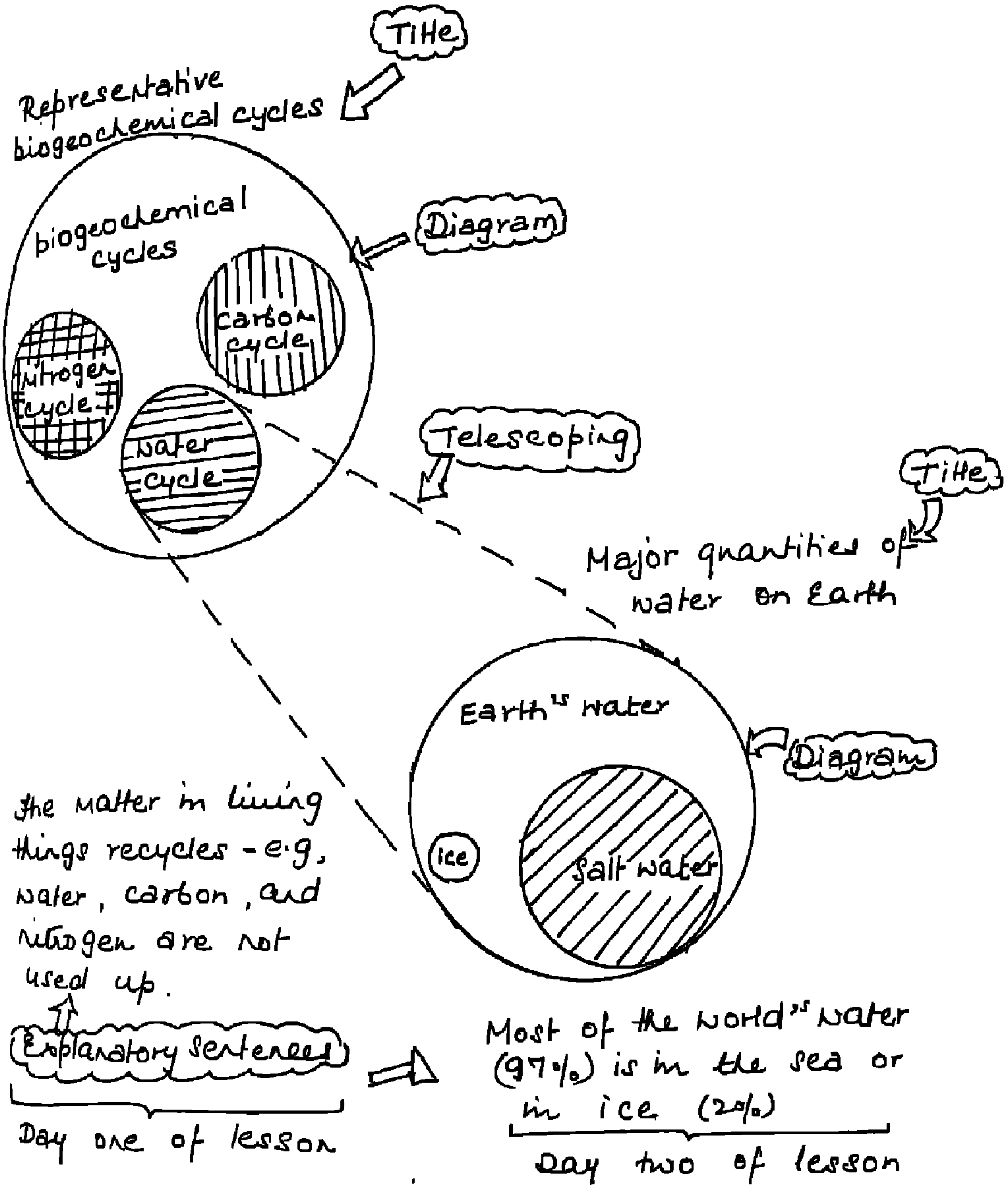

Title
Representative biogeochemical cycles
Diagram
biogeochemical cycles
carbon cycle
nitrogen cycle
water cycle
Telescoping
Title
Major quantities of water on Earth
Earth's water
Diagram
ice
salt water
The matter in living things recycles - e.g. water, carbon, and nitrogen are not used up.
Explanatory sentences
Day one of lesson
Most of the world's water (97%) is in the sea or in ice (2%)
Day two of lesson

Fig. 13

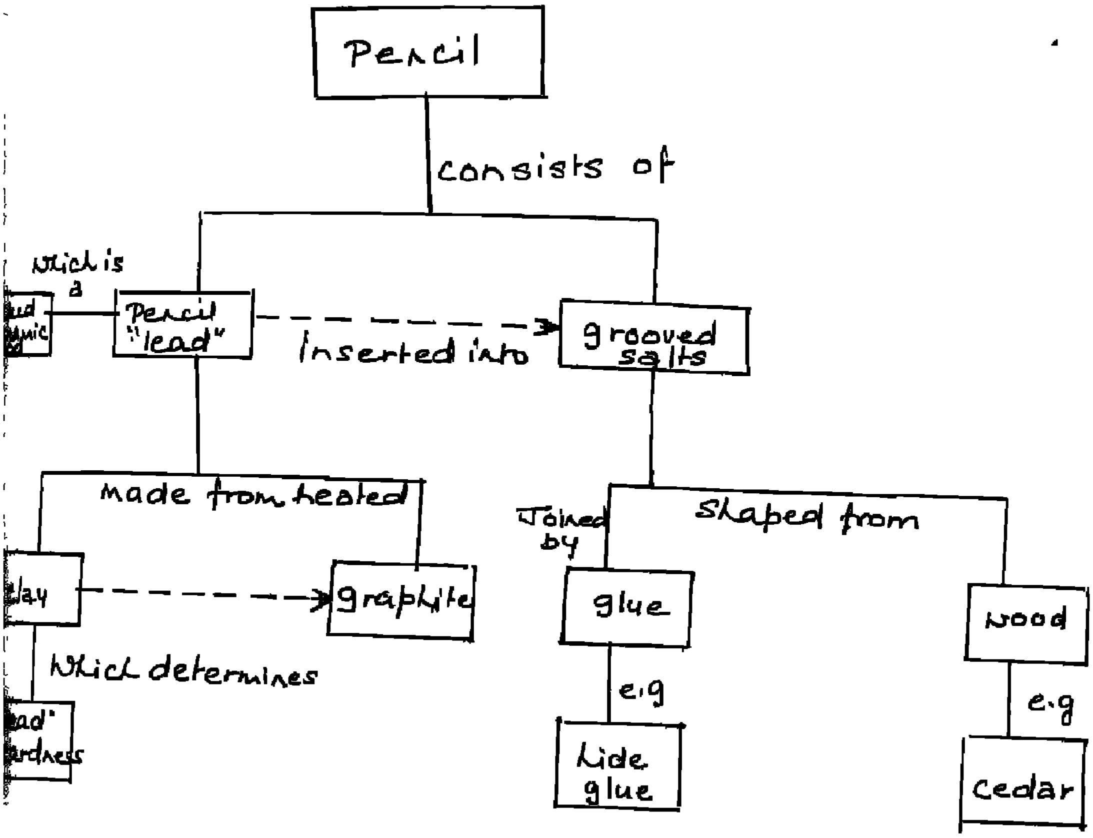

Pencil
consists of
which is a
ud
anic
Pencil "lead"
Inserted into
grooved salts
made from heated
lay
graphite
Which determines
ad"
rdness
Joined by
Shaped from
glue
wood
e.g
hide glue
e.g
cedar

Fig 14

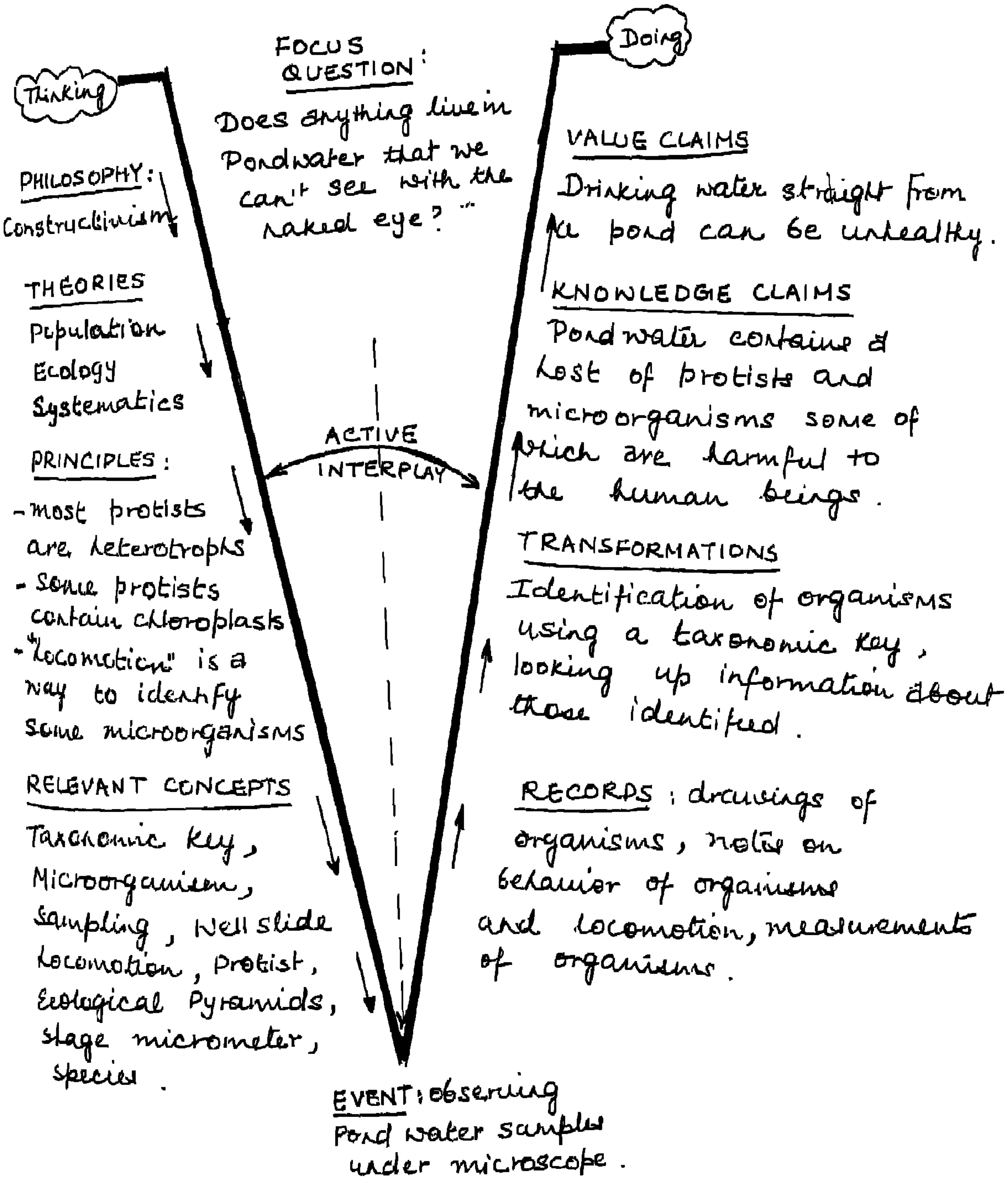

Thinking
Doing
FOCUS QUESTION:
Does anything live in Pondwater that we can't see with the naked eye?
PHILOSOPHY:
Constructivism
THEORIES
Population
Ecology
Systematics
PRINCIPLES:
- most protists are heterotrophs
- Some protists contain chloroplasts
- "Locomotion" is a way to identify some microorganisms
RELEVANT CONCEPTS
Taxonomic key, Microorganism, sampling, Well slide, Locomotion, Protist, Ecological Pyramids, stage micrometer, species.
ACTIVE INTERPLAY
VALUE CLAIMS
Drinking water straight from the pond can be unhealthy.
KNOWLEDGE CLAIMS
Pond water contains a lost of protists and microorganisms some of which are harmful to the human beings.
TRANSFORMATIONS
Identification of organisms using a taxonomic key, looking up information about those identified.
RECORDS: drawings of organisms, notes on behavior of organisms and locomotion, measurements of organisms.
EVENT: observing Pond water samples under microscope.

Fig. 15

It is then not difficult to improve the formation of concepts through maps from the practitioner's point of view for their benefit in day to day classroom teaching. Naturally, the students are going to be the beneficiaries in two ways, namely, improved understandings and that too contextually. They can also strengthen their understandings at the mutual inter-linkages of the various concepts under development at the same time. For example, young children committ lots of information to memory : naming the three forms of water, their examples, freezing point, boiling point, dew point, evaporation boiling, flow of water from higher level to lower level, solvent, volume of water, density of water, and anomolous behaviour of water and so on. However, we can raise the following questions :

(i) Let me know the places or locations where you find water.

(ii) Let me know all the possible sources of water.

(iii) Let me know the different forms in which you have seen water.

(iv) What happens when water is heated ?

(v) What happens when saltish water is heated ?

(vi) Water is boiling in a kettle. How can I get back some of the water ?

(vii) How can I get back water from water vapours ?

(viii) Sun is falling on water as shown below. Suppose it is very hot, what will happen to it ?

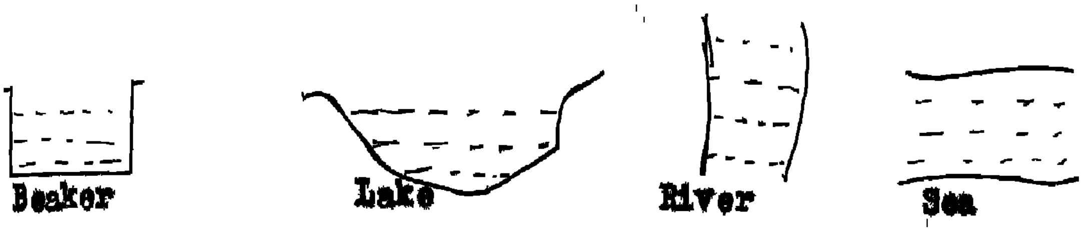


Fig. 16

(ix) Where does water go ?

(x) Where does water come from when it rains ?

(xi) Who produces water ?

(xii) Why does not the water supply on earth exhaust ?

(xiii) We have ice, snow, dew and fog etc. We have weathers which are very dry or very wet. Tell me how does it all happen ?

Children's ideas can be plotted down. Gradually they can be introduced to the scientific explanation of the natural phenomena for which appropriate explanation is not difficult to develop, using easily available local experiences and equipment. Children have their own houses of experiences and explanations. Teachers can intervene successfully on if it exists and is extended.

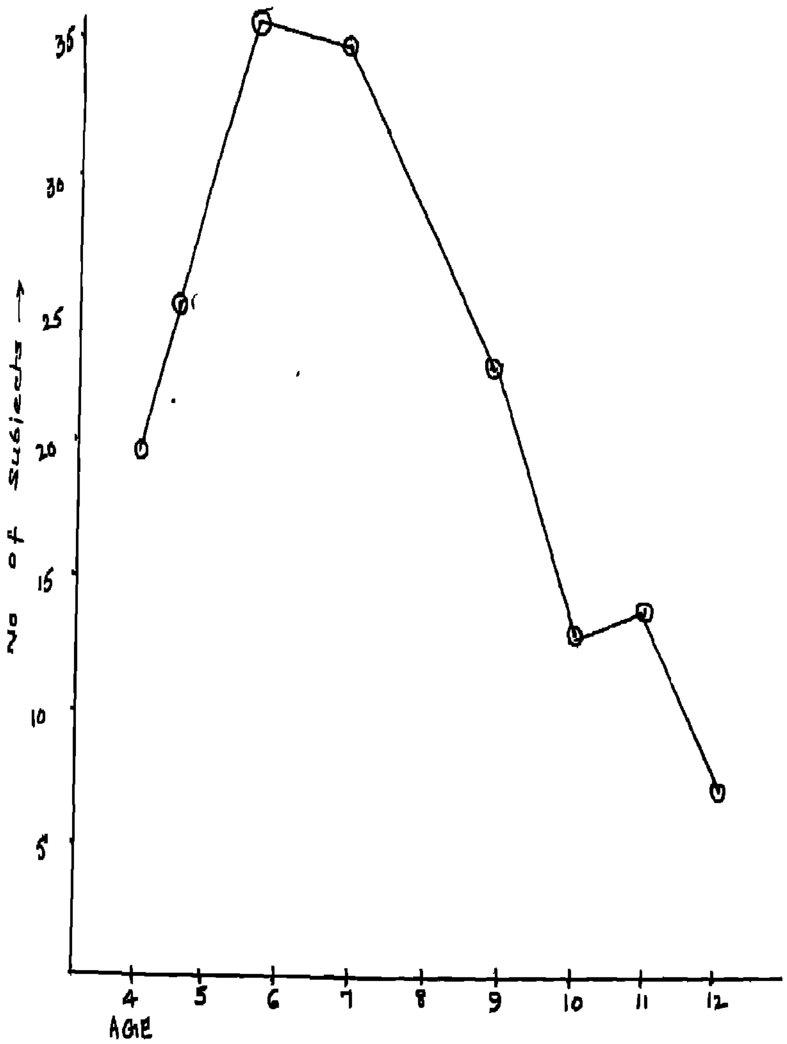


Fig. 17 It shows the number of pupils at various ages who show artificialism (Precausal explanations. The question is therefore, what is it that makes it dark at right). Aftificialism exists over a very wide range. Vaidya et al has termed that the development of concept suffers a hump effect.

It is not difficult to develop meaningful learning using diverse experiences, techniques of teaching, varied techniques of teaching and mutual discussions and dialogues in classrooms and outside. Influenceing pupil achievement then does not remain a serious problem as it is made out to be. But it does exist and can be tackled through concept mapping. Lastly, it is fair comment by the workers when they say :

> "It (mapping) is not 'magic curve of magic bullet'. It is also not a 'quickfix'. Construction of meaning is not easy to achieve but cognitive mapping is very helpful. In fact it promises a quantum leap", in improving the quality of learning and education (1[illegible].

Concluding Statement :

We have mentioned from the survey of the relevant literature practical strategies from the developmental point of view for the education of children. Their mental development need not be ignored. Why ? Teaching is not pumping content into heads; and examination pupping out of the same at the appointed day and hour. The content must be organised into meaningful wholes. In their works, Piaget, Vygotsky, Bruner and Ausubel have talked of assimilation versus accommodation; zone of proximal development, learning by discovery and advance organisers. Their ideas can be woven into the teaching learning process to a varying extent. Gestalt psychology has talked of notonly "functional fixedness" but also of proceeding organically rather than mechanically in day to day teaching.

The learning theories of behaviourism referred to conditioning and reinforcing. All this is sufficient to confuse the ordinarily busy classroom teacher. So a way out for the teacher is to start from the first principles in his classroom teaching and relate moves, later on, to the educational constructs as mentioned above. Here, the first requirement is that we begin where the childre are and not where we are. Secondly, concepts do not develop in a vacuum. They feed on diverse experiences and, later on, interpret them. Their application then is not far away. It is said that the great German scientist Kekule used to recommend to his student :

"Boys, sleep with the problem and learn to dream". "Your problem is more likely to be solved".

We follow this suggestion. We also follow the various heuristics of problem solving (See the chapters on thinking and problem). Do we then arrive at the solving ends of the problems ? The answer is obviously a big "NO"!. With exception here and there, mind has to do its own home work. It has to be trained in problem solving. While training it, its natural growth of mastery over environment has to be understood under diverse political and socio-economic condition. Here Piaget shows 'a' and not 'the' only way. Let us find them ? When successful, the acceleration of thought ceases to be the sort of problem as the American psychologists and teachers have made it to be.

PART - II

Further

Theoretical Considerations

Delving deep
into
Science Education

Prof.N. Vaidya

Delving deep
into
Science Education

Prof.N. Vaidya

Delving deep into science education

The field of science education is developing fast in several parts of the English speaking world. However, certain difficulties have cropped up because we are simultaneously working on several of its dimensions, these being philosophical, psychological, sociological, empirical and local. How can all those dimensions pick up and interpret the highly varied contents of natural sciences to children who differ very widely in intelligence and live under diverse socio-economic circumstances ?. At home, we have had a try with "Basic Education" under the leadership of our M.Gandhi with local environment as its base. This entire story is long but the fact is that efforts have been made to improve science education everywhere. These efforts include investigating the concepts of children's minds; open-ended teaching, developing SOLO Taxonomy, inquiry skills; use of life centred situations; development of assault courses; hooking science to technology for developing problem solving modules; integrated courses; and computer literacy and school studies programmes. We have had the benefits of the country-wide science show and the Science Youth Project (USAID supported) under the leadership of

Prof. Irwin Slesnick and Professor Susan Thornton, two science consultants attached to the Regional College of Education, Ajmer in the mid sixties. We have had other experimental projects: The Hoshingabad Science Teaching Project in Madhya Pradesh; and the Individually Accelerated Science Teacher Education Project at the Regional College of Education, Bhopal and Ajmer in the seventies.

We have had our energetic solutions whose transfer efforts across other schools were not as much we had expected. Paradoxically enough, facility rather than necessity ceased to be the mother of invention. Our irreducible domain of work arose out of several dimensions to the emerging field of science education which need to be firmly handled by the imaginative minds. Revolution in science teaching of the late fifties has provided us ample opportunities to work efficiently in science education. We can again raise questions about the nature, purpose, functions and limitations of science education in a wider frame-work. What is at stake is the quality of life which is within the realms of possibility because of the rapid double edged advances being made in the field of science and technology. Research in science education even then is going to be the major beneficiary on a large scale. Lastly, delving deep and deeper into science education is going to exert noble and nobler influences on all of us at the bar of scientific practices.

THE PUZZLING WAYS
OF
SCIENCE

By

N. Vaidya

Uncovering the Truth
about
Galleo Galilei

.... the fame of this outstanding genius rests mostly on discoveries he never made, and on feats he never performed. Contrary to statements in even recent outlines of science, he did not invent the telescope, nor the microscope, nor the thermometer, nor the pendulum clock. He did not discover the law of interia; nor the paralleogram of forces or motions; nor the sun spots. He made no contributiion to theoretical astronomy; he did not throw down weights from thhe leaning tower of Pisa and did not prove the truth of the Copernican system. He was not tortured bythe inquisition; did not anguish in its dunglons, did not say 'epper si muove ', and he was not a martyr of science (1).

A Koestler
in
Sleep Walkers

...2

Introduction

It is difficult to define science. It is information which speaks more to the mind than to the body. Historically speaking, it emerged from our perceptions about the world, myth, magic, folklore and finally, through religion. It was earlier a part of philosophy from which it seperated itself in the 17th century in the wake of renaissance. At the moment, its close cousins are; religion, art, poetry, law and technology. As it progresses, it does not discover any ultimate truths. On the other hand, it simply finds better approximations to truth. it is in the nature of science that its verdict is never final which, in other words, means that scientific knowledge is provisional in character. Its peradigim (framework) moves forward while looking backword. Unlike history, it eats up its own past. It flourishes on misunderstandings, nay, it is more romantic than usual when it faces a crisis chaos. it is a poor appreciation of science when it is equated with the slogan such as that science is doing. In fact, it does a better job than trial and error. Whiel trying to grasp its underlying nature, we must not only understand scientific ignorance but also scientific error. The scientist works at the close edges of observation, hypothesis and technique. It is also not

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to be confused with engineering and technology. for example, the sputnik of 1956 was a technical rather than a scientific achievement as the latter was made out to be then. Similarly, inventor is not a scientist too. Of course, he mades use of science and technology to suit his fancy. Following the same argument and if one goes deep, pencillin is not science. See thus, there is a distinct difference between religion and the cathedral. In the 17th-18th century, Samuel Johnson was quite critical when he set out to anatomize the idler. he defined him as a person who, while pretending to be busy, achieves nothing in his life. He included in this category both biologists and meteorologists. The former spent his time in collecting files and the latter, recorded the changes in wind and died fullyconvinced that the wind is changeable.

According to ERIC Ashby, the first industrial revolution in England was shaped by hard heads and clever fingers. L. Pasteur was must more forthright when he commented hardshly on the poor cultivation of sciece in France. Why is it that France does not find an outstanding scientist in the times of crisis ? He cannot even grant a petty sum of 50 cents for supporting experimental work of his fellow scientistss. According to him, anycountry which, strictly speaking, supports applied sciences is doomed to failure. Why ? According to him, one need not

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overbother about the fruit at the cost of tree from where it stems. In other words, it means that the scientists needs a differet kind of attention. Despite there limitations, man, apart from satisfying his physical needs of food, shelter and clothing, developed his mind to satisfy his curiosity. Even in the distant past, it was the function of science (phylosophy) to aim at the understanding of things and contemplation of truth. A life dedicated to the study of science or glory of heavens was regarded a life of happiness. 'Blessed is he, ' said Euphrides, 'who has accepted the responsibility of seeking knowledge, accepting in the process, contemplations on the ageless order of deathless nature .... how it can to be formed, its manner and its way ' (Crombie, 1963). They wewre equallycurious of riddles, for example, 'How many times the length of its legs does a flea jump'? As it progressed, it fed on its decay for it is the business of science to go wrong (J.R. Oppenheimer). This erratic act is subject to self corection, and provides facts and concepts which sterengthen each other when put to test to seek further clarifications. This phase of science turns out to its creative aspect (Jacob Brownski). It is necessary to point out at this stage thhat Scientific Method, by itself, does not constitute science for it has to 'make

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use of a third type of statement by which the language of the abstract principles can be translated into the language of observation' (Philip Frank). Therefore, the highest court of appeal in science is not the individual but the book of Nature.

Man mastered nature gradually and was feared by those who did not possess such mastery, animals included. he snatched curious knowledge from nature, speculated on it and put it to further tests and applications. In this game, he began to acquire magical powers. Even in this ecouter, he did not hesitate to develop possitive attitudes towards life and began to reflect over the glory of the distant galaxies in the heavens. A person interested in this exciting enterprise became more important than his own physiical parents. And we in this country still suffer from the hang over of the age old concept of "Guru". The Bible asked Christians to be 'masters rather than servants of creation,' a faith which gave a shot into the arm of Western science and engineering. Mohammed made it compuslory for every Muslim to acquire knowledge for it was his sacred duty: 'Read in the Name of God..... who teaches man to write with pen who teaches man things he knew not.' The superiorityof one Muslim over another lay in possession of more virtue and knowledge than power of the sword, strictly speaking (Arasteh, 1966). Jabir, influenced

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by the Brethren of Purity, advocated the use of experimental method in the development of natural knowledge (philosophy). It is now learnt that scientific experimentation does not invariably lead to clear cut results. Scientific evidence, even when collected painfully as well as objectively, does not yield solutions which become immediately acceptable. These solutions have to fight for their survival. Consequently, failure in science is not a rare event. It is not contingent upon workers to put the same question, same hypotheses and follow the same leads in scientific investigations. It is only then the various paths begin to meet and present tentative view of rality. How ? Science pushes doubt as far away as possible. It attempts to eliminate inconsistencies, diversity of opinion, inconclusiveness of common sense and finally, logical uncertainity and absurdity. Science is more than tested commom sense. In fact, relativity and quantum mechanics rang the death knell of common sense, for example, Heisenberg's uncertainty principle. Lastly, science comprises a series of small steps, one leading to the other, and finally, a step to thelarge and larger vision.

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The definition of Science

It took centuries for science to separate itself from its mother knowledge (philosophy) before the experimental tribunal of science was born in the seventeenth century. Then followed immediately revolutions in mechanics, chemistry and biology in succession. Right from the beginning of the 20th century, scientific knowledge began to double itself afte every ten years. Philosophers, scientists , mean of public affairs land even laymen too have reacted to the form, content, direction and destination of science. It is a powerful giant which needs to be tamed. Otherwise, it threatens to eliminate the entire mankind itself from our earth. Several thinkers like J.L. Jehru, Warre Weaver, Paul Weiss, J.B. Couant, F. Fitzpatrick, J.W.N. Sullivan, Albert Einstein, W.J. Jacobson, Cedric Griggs and Percy Bridgman have defined science in one way or another from their respective points of view. The writer also carried out this exercise and came with the following observations which encompass almost all that has been said about the natures, spirit and scope of science. The phrase like definitions of science are:

(1) Magic, trick (2) Health happiness and comfortiness (3) Engineering technology.

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(4) a thing of the highest glory
(5) a productive and proficient cow
(6) economic growth
(7) a classified common sense
(8) Not phenomenon but ways, explanations and speculations
(9) knowledge and understanding
(10) Pursuit of knowledge for its own sake
(11) Pursuit of evasive truth
(12) Topography of ignorance
(13) mixture of fact and fiction
(14) way of living or thinking
(15) Inquiry: stable and fluid
(16) Core and frontline
(17) puzzle solving
(18) ordered technique as well as rationalized mythology
(19) systematic interpretation of nature into a frame-work of law
(20) everyday common experiences
(21) discovery of general principles
(22) observation, exploration, experimentation and investigating along with its functions viz. control and comprehensions.
(23) asking appropriate questions
(24) organized, systematized, material knowledge deducible from a limited number of principles
(25) Verification
(26) forming and testing of hypotheses against observed facts
(27) discovery of causal system(s)
(28) experience in search of meaning
(29) developing concepts that make observations coherent and logical.
(30) in aDDITION, predective

Such phrases do not lead anyone anywhere. It is as well a tool of economic growth. It is a speculative

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enterprise: static as well as dynamic. It is neither gadgetry nor technology. It is a process rather than a product. According to W. Pauli, the "aim of science teaching is not the acquisition of information but to attain the understanding of the relationship which connects the answer to the problem".

Its critical appraisal

Let us now reflect over the above mentioned definitions of scienc. It becomes quite evident on reflection that it has proved a difficult exercise to search for a single ominibus definition of science either in a single key statement or a series of such statements. It appears to share its fate with the definition of intelligence, a suspect entity now, after the psychologists have worked too much to dig it out. In a science and technology weighted society, it appeas to be as vast as life. In this wide frammework, it is not possible to define science because it is not an isolated subject or even subjects having a well defined face, say, like that of a chemical crystal. Cumulatively speaking, or right throughout its historical development, it did have neither a biginning nor is it likely to have a terminal point. It tends to take the character if an intervening theme where scientists have to define their terms as clearly as possible. Secondly, there are several aspects of it which intermingle with each other

indistinguishably. Like historical dates places and figures, science is not merely a body of hard and stubborn facts. Both then devalue history and science conceputally. It is a mixture of facts and unfacts which necessarily and invariably are seen selectively. It is also not merely a body of concepts and principles alone because there is no sanctity about the fundamental ideas of science. The more they are exploded, better is the resulting scientific body of knowledge. For example, the beloved atom of the Greek philosopher, Democritus or for that matter still earlier that of saint Kanad is now no longer at the base of our universe. Further, little is known about the psychological formation of the basic notions in science. Facts concepts and skills take the scientists to the frontiers of knowledge but the latter are pushed back only by the scientific methodology. It is also not commonsense, classified or otherwise, because it can conflict with tested knowledge. The Theory of Relativity as propounded by Einstein goes interestingly far enough in contradicting almost all our common sense ideas held about this world as seen in the poetic fancy below.

There was a young girl called Miss Bright who could travel much faster than light. She departed one day in an Einsteinian way, and came back on the previous night.

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Secondly , it will be a miserly and poorly appreciation of science if it is identified with up-to-dateness, modernity, progress, health, happiness, leisure, Beecham's powder, engineering, technology and even economic development as now-a-days, strictly speaking, conceived in the developing countries. In the micro-world, decision making elements in scientific methods, that is, thenature of inductive inference has become questionable because of the intrusion of probability and chance. This has resulted in not getting a clear verdict either way on the truthfulness or falsehood of a partdicular hyupothesis under test especially when it happens to be partly true meaning 'thereby that it would become more nearlyso with the adjunction of further hypotheses'. To put in other words, it means that the yound bride of the twentieth century can only talk about the chances of her marriage on a particular day in contrast to her counterpart who could announce the same with absolute certainty in the nineteenth century. In addition, it is also necessary to translate the language of abstract principles into the language of observation using linguistic analysis according to Philip Frank. What then exactly is the role of science ? Its role or function is providing an intellectually and aesthetically satisfying experience in the pursuit of knowledge; and for its practitioner, its spirit is free enquiry -- no sacred cow to worry

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and proof, respect for mathematical arguments jand logical proofs including statistical reasoning, suspended judgement, acceptance of warranted conclusions and willingness to change one's opinion in the light of new evidence are the ferments which characterize the scientific enterprise.

What is science then ? It is puzzle-solving or an exercise at abstracting and reabstracting knowledge and skills with a view to approach and understand the unknown. This is done through diverse ways which embrace in one form or another the so-called steps in scientific methods; observation, problem survey, formulating and reformulating problems, setting up hypothesis and control experiments, suggesting plausible explanations on the basis of evidence collected, finding exceptions, developing, using and refining concepts, mathematization of arguments and their application to dig new knowledge, finding pinciples and laws, and lastly developing relevant theories which influence our global out-look.

Interestingly enough, it is an international activity, least confined to national frontiers. Incidentally, accidentally and intentionally (through research and development followed by the commercial exploitation of scientific discoveries), it strengthens national economies, creates new resources, accelerates employment and attempts to build global outlook on problems which effect man and his society. At the same time, it is double-edged, it can kill as well as save many. (2)

The puzzling ways of science.

It is the aim of science to control and comprehend enviroment. The scientists try hard to find sense in our environment by developing concepts and devising techniques which ultimately constitute the systematized body of knowledge called its core science. These ideas or concepts do not strike the scientist all at one go but have to be developed by them over the years. This becomes cumulative aspect of science. In the progress of science, scientists question the current established body of knowledge at its weakest points, encounter anomalies and in the process, either suggest new subsidiary hypotheses to the same phenomena or alter the known concept radically to suit the new evidence. They thus explain the past evidence more meaningfully and relevantly. Sometimes, it is just the case that they keep the count of anomalies separately which remain recognized without solution for several decades and in some cases several centuries (front line science). It takes time in science for the new evidence or concept to establish itself inthe existing body of knowledge. There is thus dogmatism in science but the very change, nay, the endless change or the ever continual transformation, remains at its very heart. Why ? There is a continuous interaction between the core science and the front line science. the former is a well established body of scientific knowledge which, of

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Let us now illustrate with the help of the following example, the puzzling ways of science and their pursuit passionately by the scientists, drawn from the history of science.

(a) Niepce Nicephore, a retired officer from the French army was interested in chemical experimentation. He believed strongly that light could produce pictures of reality if allowed to fall on certain chemicals. He was not the first person to hit upon this idea. Earlier Leonardo da Vinci had designed a pin hole camera. A little later, a German monk had put a lens in the hole and produced sharp images. Niepce Nicephore was not satisfied with these pictures for he failed to preserve them. he searched for some materials sensitive to light which when exposed became insoluble in vegetable oils. Through hits and trials, he got hold of asphalt but the whole process of obtaining a picture on it was a very tedious job. He, therefore, searched for new materials and considered iodine-silver as a successful base for asphalt coating. He had little knowledge of chemical and so he could not imagine, that he could now dispense with asphalt altogether. He was a sercher and spent twenty hard years on this complex enterprise. By chance, he now came to know Jacques Mande Daguerre who was already working on this problem. In 1825, it is of interest to mention that his wife asked a well-known

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chemist named Jean Baptise Dumas whether her husband was mad or not in this hunt of the proverbial goose. Both collaborated and obtained positive pictures but the progress on the patient road to discoverywas little. Niepce Nicephore died and Daguerre perserved alone. In 1837, he found that his spoiled plates, when placed in a cupboard for a couple of weeks, on washing for re-use had produced beautiful positive pictures. He was wonderstruck and again repeated this happening. Again he got pictures. he did not believe in miracles but in chemical means. He searched his cupboard in vain but failed to find any causal agent. he took a magnifying lens and found a few drops of mercury in the tiny fissures of the cupboard. he had moment of his insight, that is, the vapour of mercury had done the trick. he tested this hypothesis by placing plates in the atmosphere of mercury vapour in the dark rooms. Magically, the picture ccame on the screen. Photography was thus born. Notre Dame stepped down majestically on the plate very faithfully to be carried home by anybody (5). There were some enemies as well, particularly speaking, Daumier. Baudelair went a step further and declared:

> These are deplorable days in which a new industry contributes to the maintenance of stupidity and to the desoruction of all that has remained divine in the spirit of France (6).

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(b) It is always preferable in science to provide an explantion as well as to calculate a result, howeve, wrong the two may be. They Prrovide paths in a pathless territory. If the two turn outto be wrong, these can be rectified or left altogether. Let us ask a simple question. Why does the flame soar up ? And, why does the stone fall down? Why does gravity act that way ? What ought to be explantion when the concept of gravity is not known ? According to the Greeks, it is the habit of the flame to go up. Similarly, it is also the habit of the stone to fall down or roll down. Every school going student smiles at this explanation today. We should not be surprised that two thousand years were to roll before Newton explained the phenomenon of gravitation. They did suggest that stones sink because of their earthyform of matter, while, say, wood floated because it had water and air in it. Morever, trees and plants grow in soil and so, earth must be an important constituent of them all. On burning, the same sort of fire comes out of them all. Naturally, they must all have 'fire' in their composition. What would be our explanation today of this phenomenon when, say, we are caught in a thunderstorm without any shelter ? Was then the old theory so wide off the mark ?(7).

(c) There is hardly a field of work as interesting as science. Magnus Pyke in his book: "Nothing Like Science" makes certain significant observations. Science is much more than knowing that acid turns blue litmus red and, in turn, alkali turns it blue. Or, there is hydrogen sulphide in he air .when rotton eggs are there nearby. Chinese invested tne mariner's compass but it was used by the West for steering ships on the sea. They also mae crackers for rejoicinng at the festivals but it was again in the West that gun powder was used in war as a matter of public policy. Malthus was wrong in stating his law because he did not expect the starvving population to develop foresight. When given a choice, rats are in a position to select balanced nutrition for themselves. It is possible to grow rats as big a children on right lavish nutrition but that does not increase their longevity. In fact, it depends upon alternative periods of plenty and deprivattion in their early life. According to V.M. Holt, chees mites are freely eaten by many persons as part of the cheese. If so, what is the objection like if cabbage wrorms are eaten too ? Not long ago, a dietary survey among Otomi tribes in Mexico showed that the people had higher nutritional content than the corresponding group of Americans settled nearby. They ate none of the foods known to the Americans. They, on the other hand, depended upon pigwood, sow thistles, cactus fruit,

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termites, caterpillars, locusts and other insects. The lesson to learn is that man should eat as widely as possible.(8).

(d) What happens when one fails to achieve the main goal but, instead achieves something remarkably more than which was not sought. The case in point is that of alchemy, frenzied alchemy which gripped the world for more than seventeen centuries. The problem was how to change an inferior metal into gold. Even the Roger Bacon of Oxford tried hard to tackle this problem. Bernord Trevisan died in vain in 1490. Even the world kown scientists: Newton was not an exception. Robert Boyle, the president of the Royal Society of England, approached the parliament for a legislative measure successfully. Thus alchemybecame a respectable activity. Francis Bacon compared this effort to the intense and exciting activity of the lazy sons of a wise farmer who, just before his dealth, asked them to obtain gold hidden somewhere bydigging deep the vine yard.. Result was a rich harvest. Whereas the alchemists failed to synthesize gold, they gave us several industrial and other products such:

(i) Acids (nitric acid, sulphuric acid, hydrochloric acid and aqua regia (a power solvent for gold).

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(ii) Elements like: arsenic, antimony, bismuth and phosphorus.

(iii) Common chemicals (alum, borax, ether, plater of paris, red lead, silver salts and borium sulphide which glowed in dark after exposure to sun light.

(iv) Apparatus and utensils for the chemist: flask, retort, water bath and balance.

Discovery of techniques, say, for the preparation of caustic alkali from the ashes of plants and extraction of gold by amalgamation with mercury etc.

There were other powerful myths and beliefs too which had a long history. Paracelsus fought against such vested interests and commented harshly by calling such unreflective authorities as "misbegotten crew of approved asses".

It was a case of blind groping which paid rich dividents (9).

(e) Every school student knows that a freely suspended magnet points towards North and South. A curious student or a serious scientists goes a step further by asking himself: Is it really true ? Let me find out ! George Grahm, a famous London Clock maker, asked himself this question. In seeking answer to this question, he was very much troubled by the London traffic

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which affected his observations. In the process of experimentation, he had to design a mirror and metre arrangement for making his observations very sensitive. He found that the magnet does move by a small angle. Michael Faraday was also curious about this phenomenon who attributed this amll deflection to the slightly magnetic property of Oxygen. Lord Kelvin found that the magnetic variation occurs during daytime only and attributed this phenomenon to sun's magnetism. Others put several ther hypotheses. Bmalfour examined these hypotheses critically one byone and after eliminating all except one came to the conclusion that the cause of magnetic variation during the day time lay in 'horizontal electric current flowing during the day in upper atmosphere'. No crucial test to test this hypothesis was available then. Later on, part of the evidence was provided by Lord Appleton who showed that the upper atmosphere behaved like an electrical conductor whose conductivity, like the daily variation of earth's magnetism, varied with sun spot activity in the sun. Not long ago, American scientists sent rockets in the upper atmosphere; and deflection in magnetometer showed the existence of ionized gas about sixty miles above the ground. Thus the grant hypothesis became a theory (10).

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(f) The chemists had analysed several inorganic gases, studies them and propounded the atomic theory. When it came to the analysis of organic compounds, they found that their basic concepts so relevant to inorganic chemistryy failed so miserably when applied to organic substances. For example, two organic substances, ethyl alcohol and dimethyl ether, had exactly the same chemical composition (two carbon atoms, one oxygen atom and six hydrogen atoms) but different properties, that is, one is a gas and the other a liquid. Why this anomaly ? Berzelius then propounded that the Chemistry of Living Things swas something different which had its own subtle rules. In his opinion (firmly held and shared by many chemists of the day as well), only living bodies could produce organic compounds. In 1828, Friedrick Woehler prepared an organic substance in the laboratory byheating ammonium cyanate. It, on further testing, turned out to be Urea, a component of Urine. It was impossible, according to the tenets of Berzellius because human kidney was necessaary in the manufacture of Urine. Woehler repeated this experiment a number of times before he made his discovery public. Interestingly enough, Berzellius and other well-known chemists of the day refused to trust this discovery. But more confirming evidence from other chemists poured in. Thus same laws applied both to inorgaic and chemistry. Only the configuration of atoms was different (11).

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(g) Take another example. John Logie Baird, born in Scotland in 1888, wanted to attempt something big in life. During his childhood, he was interested in technical things. His telephone wires badly inconvenienced a coach man for which he was strictly forbidden byhis father not to carry on any more excursions into the electro-technical field. He obtained a degree in physics and electricity. Due jtohis bad health, he could not continue on a job and, therefore, started business which was again a fruitless adventure. He sold socks, Osmo boot polish, jam, Australian honey, coir fibre dust and French soap. Now he had two options left, namely, tinkering with razor blade and television. He was advised the former but he chose the latter. As already mentioned, he had bad health and on top of it, had bad financial condition bordering on starvation. he had little chance of success in this venture for the theoretical solution of the television waas known for the last forty years. The whole scientific community talked of insuperable difficulties to be mastered but Baaird did the trick. He carried on this self-imposed task. Consider, what did he do ?

> Baird's wash-stand became the base of the whole apparatus. It was joined by an old tea-chest, purchased for a few pennies, as a stand for the electromotor

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which the impecunious invéntor had found on a heap of jumble behind an electrician's shop, and which was assigned the job of turning the scanning disc, cut out of a piece of card board. An empty biscuit tin was to house the projection lamp, with lenses at 4 d. each from a bicle shop. Further ingredients were parts of a 'disabled' military wireless telegraph, some darning needles, a couple of torch batteries, some old scrap timber .... all held together by glue, sealing wax, and bits of string. Around and across the whole laboratory, there was a labyrinth of electric wire.

In 1924, he succeeded to transmit the external features of a doll over a distance of three yards. He got Mr. Day interested in his future patent who paid him over 200 pounds which he demanded back soon after, for in his **opinion**, his patent held no promise. In 1925, he got a lucrative job at a departmental store (Selfridge) on 25 pounds per week for demonstrating jhis device. He left the job for he was more interested in perfecting his equipment than in demonstrating his queer piece. Again he got into extreme financial difficulties but luckily got 500 pounds from one of his cousins. Newspapers did not find a story worth publication on what

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he was doing. One day, he suddenly succeeded to televise an office boywho needed a half crown to obey and bear the instructions. Thus the Magic Looking Glass was born. Interestingly enough, he had to wage a war against the B.B.C. which refused to see any benefit of this discovery for the British people. He sought parliamentary intervention ,and was successful. (12)

(h) The beading of a seedling.

Science is a matter of 'meticulous observation and unrestrained speculation' (Eric Ashby). Merely counting the teeth of a horse, donkey or man does not constitute an act of science. It is only a step towards it. It tends to become science only when one attempts to describe the number and arrangement of teeth in different animals called dentition. Efforts become quite powerful if they result in the discovery of a mathematical relationship. Thus it becomes possible for one to 'Assign the bewildering diversity of mammals to one or other of a few easily remembered categories'. Let us illustrate:

All of us know or it can be verified any way that an oat seedling when placed near a window bends towards light. The bending occurs at a point just over 6 mm away from the tip. The question arises: What is the cause for this bending? Charles Darwin also observed this phenomenon. He found further that bending does not occur

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in case ti ps are removed or covered with tin foil caps. He hypothesized that the tip gets something from light; and in turn transmits a message below for the bending to occur. Boysen-Jensen confirmed Darwin's observation; and followed up this observation by showing that Seedling grows vertically in uniform light; and the Oat Seedling ceases to grow in case its tips are cut off. They made another interesting observation. This phenomenon repeates itself when the severed tip is put back on the stem itself. They, therefore, concluded that there is something (Stimulus) in the jtip which not only controls bending in oblique light but also maintains straight growth in uniform light. Now another additional subsidiary hypothesis appeared. The severed tip, if replaced on the stem, is also able to transmit the stimulus. Now the question arises; what causes jthe stimulus ? At this point, they further hypothesized that stimulus is either a nerve impulse (Electric current) or some chemical substance. This could be tested by placing a minute cube of gelatine between the severed tip and the stem. The choice of the gelatine cube rested on the fact that the nerve impulse and not the chemical substance would be fully resisted. In 1928, Went in Holland thought of collecting this chemical substance in blocks of gelatine and succeeded in his efforts. Wheras he failed to name the substance, he did succeed in an other direction. He developed a technique in collecting this substance in the tip in certain units.

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Kogol, with careful experimentation, collected this growth promoting substance in sufficient quantity, analysed it, isolated it, and named it as "Auxin'. Fifteen years later, it was found that it was not 'Auxin' but some other jsimpler substance. It is in the tradition of science, where the credit is due, the name of Kogol is just not mentioned.

It is interesting to note that it took about seventy-five years for partial understanding of this problem when Charles Darwin gave his first vaguely worded hypothesis. Currently, the position is that the efficient cause of growth as well as the cause of bending in an Oat seedling is known to be a chemical substance. Not only the constitution of this chemical substance is known but also the chemists have succeeded in synthesizing it. Several additional investigative questions have turned up during the solution of this one time least understood problem. For example, 'Why is it that only this substance and not other substance with similar chemical composition helps in growth ? Is it suggested that it is related to the specific configuration of atoms in this substance ?. 'What other growth promoting substances criticallycontrol plant or animal life ? Science appears to advance forward by unfolding a chain of mysteries .(13)

(i) A mysterious nervous disease

W.H. Bennetts investigated a mysterious nervous disease which inflicts sheep in Great Britain and Australia. He first hypothesized that this might be due to lead intoxication. He, therefore, treated some sheep with ammonium chloride. The initial results appeared to be quite promising but the latter were not. From this, he got a clue that [illegible] might be due to some mineral defficiency. He followed up this clue; and through experimentation pin-pointed the cause of this strange disease,, namely, the deficiency of copper. It had never been even suspected in the past that the deficiency of copper ever produced a diseas in an animal. At this moment of triumph, his thoughtful remark needs careful consideration: Hypothesis is neither jright nor wrong nor definitive; and it simply attempts to direct our probings. (9, 14)

(j) It was in the year 830 that Geber discovered that three substances, iron, lead and copper gained weight on heating., The fourth element to the list was added by Lord Robert Boyle in the seventeenth century. And it was in the eighteenth century that Lavoisier supplied the true interpretation. His laboratory observations, during the process of reconciliation, led to the discovery of chlorine and carbon monoxide. He spent thirty years in recording

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faithfully barometric readings for identifying clearly the variables which affect weather. He heated water for not less than 101 days in a special type of flask (Pelican) to refute the theory held for several centuries that water was transmutable into earth. This was despite the fact that Lavoisier had ill health as well as other official duti[illegible] 15). Let us take the example of another metal called aluminium. Both its discovery and application are instructive to read and think about.

Aluminium was a rare metal in the closing decade of the nineteenth century. Professor Frank Jewett talked about the history of this rare metal and its importance in the world of commerce in his class. Oersted in 1825 isolated this material. So did Wohler in Germany, using an entirely different method. Both obtained this material in small quantities and that too in the form of a powder. In 1854, Henri De Ville managed to obtain metallic aluminium by reducing aluminium chloride withmetallic sodium. It was still so rare that the Prince Imperial of France (Napoleon III) wore with pride the helmet made of aluminium. He also served dinner on aluminium plates to the most distinguished gentry of Europe in Paris. From 1860 to 1880, the yearly production of aluminium was about

a ton and half. Charles Hall, the student of Professor Jewett, accepted this challenge and said to himself, "I am going to get that metal". And he did (16).

(k) The discoverer of some chemical elements

Let us consider the wwork of William Ramsay(1852-1916). In 1785, Cavendish passed electric sparks in a mixture containing atmospheric nitrogen and excess of Oxygen. On removing nitrogen Oxide and Oxygen, he found that a very small quantity of the gass was still left which, of course, did not exceed 1/120th of the original volume of nitrogen. On reading this account, Ramsay had noted: 'Look into this'. He possibly forgot all about this but was soon remined by Lord Raleigh's Open letter in 1982.

> I am much puzzled by some results as to the density of nitrogen and shall be obliged if any of your chemical readers can offer suggestions as to the cause. According to the two methods of preparation (Nitrogen gas), I obtain quite distinct values. The relative difference , amounting to 1/1000 part, is small in itself, but it lies entirely outside the errors of experiment.

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Ramsay joined Lord Raleigh and both of them now attacked this problem jointly. They discovered a new gaseous element, namely, Argon. This was not the end of journey for Ramsay. he made a strenuous search for all the possible compounds of Argon. He even studied several minerals containing Uranium which, on dissolution in acid, released a gas presumed to be nitrogen. He found hat the released gas was not nitrogen as hypothesized by him earlier. Of course, it certainly contained Argon but there was another gas, hitherto, unknown on earth. On spectral analysis; it gave a clear and brilliant yellow spectral line. Here is another example where two independent scientific paths happen to cross each otther. Earlier a French astronomer had found this line in his spectral studies, on the atmosphere of the sun. Further, Frankland and Loockyer stated that this line was due to the existence of a new element in the sun for which they had suggested the name of Helium. A small anamolous observation on being followed up by careful and extensive experimentation, systematic analysis and flash of imagination brought jdown helium from the sun to our abode. About this discovery of Helium, Ramsay wrote to his wife on March, 24, 1895 as follows:

> Let us take the biggest piece of news first. I bottled the new gas in a

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> vacuum tube, and arranged so that I could see its spectrum and that of Argon in the same spectroscope at the same time. There is Argon in the gas; but there was a magnificent yellow line, brilliantly bright, not coincident with but very close to the sodium line. I was puzzled but began to smell a rat. I told Crookes, and on Saturday morning when Harley, Shields, and I were looking at the spectrum in the dark room, a telegram came from Crookes. He had sent a copy here and I endorse that copy. You may wonder what it means. Helium is the name given to a line in the Solar spectrum, known to belong to an element, but that element has been hitherto unknown on earth. -- It is quite overwhelming and beats Argon.

In 1898, he reported other gases like neon, krypton and xenon, and radon (radium emanation). Let us sidetrack for a while here. It is of interest to note that an American scientist named W.F. Hillebrand had examined a sample of mixture containing both Argon and Helium before 1890, but had failed to

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identify correctly. He discovered that certain minerals on reaction with acid gave off nitrogen. He repeated the experiment and found that the newly evolved gas was not nitrogen but a mixture of gases containing Argon and Helium. Ramsay investigated thoroughly and successfully whereas the American scientist remained very close to this discovery. After Ramsay's success, he had these comments to make onn his failure:

> The circumstances and conditions under which mywork was done were unfavourable; the chemical examination had consumed a vast amount of time, and I ffelt strong scruples about taking more from regular routine work. I was not a novice at a spectroscopic work of this kind. It doubtless has appeared in comprehensible to you, in view jof the bright Argon and other lines notices by you in the gas from clevite, that they should have escaped my observation. They did not. Both Dr. Hallock and I observed numerous bright lines on one or two occasions, some of which could be accounted for by known elements as mercury, or sulphor from sulphuric acid; but there were others that I could not identify with any mapped lidnes. The well known variability in the spectra of some substance under various conditions of degree of evacuation of the tube led me to describe similar causes for these anomalous appearances, and to reject the suggestion made byone of us in doubtfully serious spirit, that a new element might be in question.

Who are wise before the event ? Only a few Who can pinpoint discovery with absolute confidence at the scientific frontier ? The answer is obviously

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No one ? Here, one has to learn to believe in one's own answers without raising an accusing finger at anybody who may give false scent. Commitment to science requires long hours of work daily over a long period of time. In the process, one has to tolerate lot of vagueness and confusion and that too for a long time until the problem is solved. According to Peter J.W. Debye, "it is the urge to understand things that makes me study things". It may be a discrepant event which astonishes me and thus attracts scientific attention. Hence, trials and tribulations. Lastly, Ramsay's contribution is unique in the history of the discoveryof chemical elements. No other individual, single handed, had discovered a whole column of new elements in the periodic table. The chemical inactivity of elements gave his work an extra distinction. After his chemical discoveries, nature need no longer jump abruptly from halogens to the alkali metals differing completely in electropolarity.

(1) It is the natural habit of mind to correlate expriences, look for relationships and other laws and uniformities in nature. Let us now refer to the thinking of Balmer, a Swiss school teacher. He worked on the ideas of Angstorm in 1885 who had in 1851 determined the wave lengths of the hydrogen atom were repeatedly observed, confirmed and reckoned as

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expressing uniformities a law of nature. Balmer divided these numbers by 'h' called the Plancki constant. He got the figures on which he again worked somewhat as follows:

$$9/5, \quad \frac{16}{12}, \quad \frac{25}{21} \quad \frac{36}{32}$$

or

$$\frac{3^2}{3^2-1}, \quad \frac{4^2}{4^2-2^2}, \quad \frac{5^2}{5^2-2^2}, \quad \frac{6^2}{6^2-2^2}$$

which when generalized led to

$$\frac{n^2\ h}{n^2-2^2}$$

This hypothesized relationship led to predict the wave length of the fifth, sixth and seventh line of the hydrogen spectrum. Earlier efforts to seek harmonic ratios by following the analogies of light and sound had ended in vain. Interestingly enough, other lines were also discovered by Sir W. Hugins both in the visible and ultra violet part of the hydrogen spectrum by creating a vacuum. Professor Hagenback showed that all these lines followed the Balmer series. There are now 50 lines including those obtained from the light of white stars. Let us now have a look at the figure of 2^2 in the denominataor. It restricts the emergence

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of hydrogen spectral lines below the wave lengths of 6562. More lines were discovered in the inferred part of the spectrum. Their position was determined by changing the formula as follows:

$$\frac{n^2 h}{n^2 - 2^2} = \frac{n^2 h}{n^2 - 3^2}$$

What is the underlying logical justification for this achievement ? No answer is available . Its contingent character was stressed by its arbitrary constant "h" which is equal to 3645,6A°. Let us go still further. Rydbery did not take much time and 1890 replaced "Balmer's 'h' by his R (a frequency constant). This enabled to determine the postion of line spectra of other elements. Again, the 'R' had no grounding in physics. Imaginativelyenough, Bohr deduced among other things not only Rydberg's constant and Balmer's laws by applying quantum mechanics of Planck and Einstein as well as the atomic theory of the atom as propounded by Rutherford. See how over the time, the Balmer's law and the Rydberg's constant became grounded in general physics. We can then say:

(a) There is no direct relationship between increas in knowledge and increase in retionality.

(b) The following up of an imaginary idea or the vague hypothesized construct is a matter of intuition or, say, gift of God. But its labour of cultivation

to bear a nourishing fruit is a function of adjustment as well as readjustment of hypotheses; and the proper blend of arduouus scientific technique and uncommon observation at that moment.(18)

(m) Cavendish, of course, a rich man, completely absorbed himself in scientific pursuits. He was bold in his imagination. He jtried to find the weight of the earth by measuring force where two large balls attract two small balls. He came from Cambride to London without a degree. He thought that he had discovered "phlogiston" which he could pour from vessel to vessel. Instead, he had discovered the hydrogen gas. Dr. Charles of Paris used this gas in a balloon and had the first aerial voyage. He was as patient as Boerhaave who heated mercury in an open vessel for discovering a chemical fact over a period of 15 years or so. He split water into hydrogen and oxygen and synthesized these two gases under electric discharge. One can appreciate the excitement of the times when Fourcroy of France continued burning 375000 cubic inches of this mixture for a week and got nothingelse but water. Equally interesting is the case of a lady standing on a wooden stool in Berlin who was appropriately charged ith frictional electricity. Anyone who approached her got electric sparks. It is

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an excellent way of communicating science in flesh and blood to the laymen.

His life history is worth reading. He followed the same path from his residence to the laboratory and back everyday. He diverted from his path only when certain young ladies giggled on seeing him. Let us proceed still further with this man. he measured voltage (potential difference) by discharging electricity in his body from lyden fars. At that time, there were no voltameters. He predicted that $\frac{1}{120}$ th of the volume of hydrogen could not be reduced to nitrous aci. This led Lord Raleigh and William Ramsay, 100 years after, for the search of an idle gas called argon. This figure was 1 in 10 per cent after a century's of experimental advance. From this result, they separated three more inert gases, namely, neon krypton and xenon.

So, going ahead in science is like climbing up ropes hanging in air. Rises and falls of scientists take place. While he is ascending, in fact he is descending and vice versa which is more a matter of backsight rather than foresight. The ensuring difficulties are not difficult to negotiate in the very near future for the basic urge of man is to strive, to seek and to find rather than to yield.([illegible])

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(n) How is it that atom no longer remained the brick of the universe. After 20 years jof hard work, Joseph John Thomson in 1897 showed that cathode rays are particles of negative electricity. With this went away the Dalton's atom. He calculated its mass and charge in several ways and got the nobel prize, later on. In turn, about three decades after, his son showed electron as wave rather than a particle. He also got a nobel prize for confirming an opposing point of view. Neither baffling problems nor discoveries in science fall from the heaven for they are really there during the course of one's work. Langmuir attacked a very difficult problem which was to make tungsten wire survive in an electric bulb. If he followed the beaten track, only three samples out 100 samples survived successfully. What went wrong with the large number of samples? He left the beaten track of creating efficient and more efficient vacuums. It was expensive too. He had the idea that certain gases entered the tungsten filament during its manufacture. Instead, he filled the electric bulbs with gases and studied their effects on the tungsten filament. He succeeded and thereby stated the principle of research. To quote Langmuir

> When it is suspected that some useful result is to be obtained by avoiding

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> certain undesired factors, but it is found that the factors are difficult to avoid, then it is a good plan to deliberately increase each of these factors in turn so as to exaggerate their bad effects, and, thus, become so familiar with them that one can determine whether it is really worthwhile avoiding them. He got rid of the immense volumes of such gases which the tungsten filament had absorbed. He then filled the lamps with inert gases.

He, thus studied a theoretical problem of atomic hydrogen while continuing his work in applied sciences.

In 1844, Mercer, an English man made an interesting discovery of immense practical use. He found that cotton fibres when immersed in caustic soda solution swellep up, became shorter but, at the same, more stronger. It took 50 years for this process to be introduced into the industry.(16)

(o) The pursuit in science takes different corners depending upon the nature of questions asked. Take the case of J.S. Haldane, father of J.B.S. Haldane. The latter worked as his assistant and busied himself in washing bottles and making calculations for his father's experiments who had put to himself some straight forward questions such as:

(1) What is bad air ?

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(2) What makes air dangerous to breathe ?

(3) How can its bad effects be prevented ?

uring the course of his investigations, he went to arious places such as worst slums, inside sewers and ines and hospitals. He became his own object of nvestigation too. Results were seen to be negative. e discovered several empirical facts. For example, arbon monoxide is a killer disease. A mouse is as ensitive to carbon dioxide as man. All warm blooded nimals produce roughly the same same amount of heat er unit area of their body surface. Three thousand ice weigh as much as one man but possess twenty time ts surface area. And so on. Hence, a mouse or a mall bird can be used as an indicator before the mount of carbon monoxide in air becomes fatal to man. e need no longer die at once ,for carbon monoxide has o smell and causes no irritation. Life is not easy or a man of science. He has to manifest patience and erseverance in the face of his difficulties; personal, rofessional, ecoonomic and what not. If he thinks imself a bit gifted, let him process an overdose of elf confidence for othewise the scientific discovery y elude him. Let us illustrate this point with a ouple of examples.

It is in the nature of man to put questions to himself, investigate their answers as best as he can satisfy his curiosity and thereby reduce his boredom. Between two dark points, namely, present and future, he lights his candles and consequently lights up as much area as he can. He is not aware when the curtain of darkness will fall again. The pursuit of appearance, however, hazy remains his best bet. It won't be out of place that scientific discoveries have been made by several odd balls, nay, men of every temperament from, practically speaking, every walk of life. The name of Michael Farady, a book binder as well as an illiterate sccientist, is still a house-hold name. Henri Cavendish fully described hydrogen, discovered nitric acid as well as the composition of water; and computed a highly satisfying value of the density of earth which, later on, turned out to be true. He was a man of ingenuity in his time but, at the same time, suffered nearly of abject madness.

At the suggestion of his teacher in his day to day classroom teaching, Charles Hall decided to find a practical way for the manufacture of aluminium on a commercial scale. Earlier Oersted, Wohler and Henri Deville had failed on this game. He retried the technique of electrolysis, using aluminium oxide in the molten cryolite. He made batteries work by using

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containers like cups, tumblers and pieces of carbon which were available locally in abundance. There is a lesson to be learnt here. Questioning longing to know, and doby trying new methods and alternate materials are the most important attributes of a man of science.

Mental preparedness and patience may frequently as well as infrequently go together when it comes finally to drop a final blow on the head of a problem. It is a life absorbing game where the precise moment for solution of the problem cannot be predicted . For a man of technology as well as invention, problems multiply in unexpected directions. Charles Goodyear in 1833 became highly interested in the manufacture of rubber, a material highly beneficial to mankind. Personal fortunes were also at stake for him. He lived in a way in the atmosphere of rubber. He talked and thought of rubber incessantly. He wore it too. To overcome economic difficulties, he sold his domestic goods, pawned his sweetheart's clothes and sold his children's books. He begged, borrowed and starved but did not lose his tenacity of mind. Rubber continued to be sticky in summer despite its treatment with sulphuric acid. In 1839, luck would have it for by sheer chance, a piece of rubber smeared with sulphur and left over night near the burning stove became hard

by the next morning. The moment of triumph came but the battle for the patent ensured until the year 1853. Here, let us not hammer at the obvious. Success in science depends upon the peculiar combination of factors like commitment to the demands of the problem, prepared mind, grappling with difficulties of all sorts, personal sacrifices and what not from the leat expected quarters. Jules Verne, a man of strong and extreme imagination, predicted several developments in technology before these landed safely on earth. He was a source of ideas for several engineers and inventors. Srinivasa Ramanujan, the great Indian mathematician that India has ever produced, saw a lot of significance in number "1729" which could be expressed as a sum of two cubes in more than one way. And a number smaller than "1729" meeting the above requirements is impossible to find. Hewon't get a lecturing post at a rural college because he did not possess a degree. In our country, the possession of degree is more important than doing remarkable original work without a degree. Royal Society of London does not demand degrees while admitting fellows in its fold since Ramanujan getting his award, M.B. Crane also got his F.R.S. for his discoveries about fruit trees. What was he doing ? He was merely a gardner (mali).

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J.B.S. Haldane became a reader directly at the Cambridge University in England on the basis of his published work and capacity to lecture. Of course, he was an island into himself - a voracious reader who could not sleep without reading seveeral hundred pages each day. He has a message for our country too where he died. He gave his body for scientific research. And contrary to tradition, his laboratory at Bhubaneswar was not closed as a mark of respect. It is a lazy nation's tribute to a great man. He also write an open letter to Pt. J.L. Nehru before his death emphasizing the need for the recruitment of men of imagination even from the ones of social sciences for credital scientific research. He showed his own data of research output for comparison with the entire research output as published in reserch journals abroad. To quote the illustrious scientist:

> If India is to know Ramanujan as it should, the first step should be to open career in mathematics and other academic subjects to men like him having no degrees, but have done distinguished original work. Until this is done, we should be continuing the practice of British imperialism and frustrating source of our most talented men and women.

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From the psychological point of view, it is very difficult to explain such spectrums of exceptional behaviours. The whole thing is too baffling when attempt is made to determine the conditions under which the machinery of mind works within the context of individual's scientist's objectives, motives and the continuing struggle both physical and mental against environmental handicap.(16)

It is difficult to construct a perpectual wheel. If constructed successfully, it becomes an eternal source of energy. It has been an object of fascination both for scientists and inventors. In the eighties, Professor Horace Bright thought he had constructed the scheme of this perpectual wheel, say, the perpectual water wheel. His aim was to draw water out from the earth inside, using gravity and the properties of water. He needed a paltry sum of 5000 to develop a full scale model. Even the department of energy did not care. To quote:

I went to the department of energy to get a grant for my invention but I was thrown out. I was told that there was no such thing as perpetual wheel and you cannot get energy from gravity which is what my invention is all about. They are not prepared to listen to me and my arguments and they would not let

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me demonstrate how my machine works.

.... If Britain wanted to, we could produce all the world's electricity. My machine makes 1000 uits of electricity for a penny.

My employers did not help me. Anyone who saw my model was impressed. The patent office did not accept my patent for registration until 1976. My invention changed their rules because it had changed the natural laws. It could as well the case of an anamoly which is not a rare event in science. (19)

(p) Let us continue this theme of discussion where one gets a lot out of nothing. It is the existence of vacuum where nothing happens. According to Aristotle, even nature abhors vacuum. The existence of actual vacuum has been an object of discussion among scientists right from Aristotle onwards up to the present times. It is known that light, heat and magnetic fields travel through a vacuum. If so, each must have a medium for its propogation in space. So the terminology of 'aethers' appeared on the scene which provide all space. The Maxwell's theory of electromagnetism reduced the various types of 'aethers' to one just one 'ether'. The problem then arose to show the existence of ether experimentally. The famous

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Machelson Morley experiment failed to find it. It only proved that earth moves around the sun. Then it came the turn of Albert Einstein who eliminated the existence of ether in his special relativity theory. Thus, he allowed the true vacuum to exist. Then can the Heiisenberg's uncertainity principle of 1927. The atomic physicists said that particles would continue to appear as well as disappear in vacuum provided they do not violate the above mentioned famous principle. Now the quantum vacum is a very active place where all sorts of particles appear and disappear. What are the relevant facts today.

(a) The quantum theorists are correct in this interpretation. It is interesting to see that two metal pplates when placed in a vacuum a bit apart get pushed together. The reason is that more energetic particles appear outside the plates than inside the narrow separation space.

(b) The particle physicists have now started saying that the entire universe was created as a 'false vacuum' within the context of inflationary universe theory. This quantum vacuum possesses more energy in its nothingness than it should. Then the quantum jump:

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The decay of that particle vacuum to an ordinary quantum vacuum produced all the mass in the universe and started the "Big Bang".

It is perhaps the case that a baffling problem directs its own construction and reconstruction of solution i.e. knowledge. (20)

Let us now have a little peep into our own scientific community. Whatever happened in the West also happened here a bit later on, except no scientist was hanged to death or even better, was sent to the prison. We see prevalent among our giants of science poverty rather than affluence, difficulty rather than facility or opportunity, going it alone and, at times, reminding country men what ought to happen and what ought not to happen in science and technology so that our country catches up with the West in the shortest possible time. They advised firmly how to select, train and put to fruitful work young men and women rather than draw the experienced ones from Universities, and consequents weaken them. They did not think and talk of regionalism, casteism, and then even worse that of "Mandir" and "Mandal" as our politicians do so as to keep the pot of problems boiling. They were not, of course, Care Rogers but,

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on keen reflection, were Francis Bacons of the higheet order having in them the deathless spirit which continually haunts us. Their ideas have lot of sense for us even today for the nation's money has to be spent with care and caution. Those who generate ideas by carrying out disinterested research or build castles in the air which later on, may land on the ground need a different kind of attention and treatment. The nobel priza winner in physics : Max Born of Germany aptly remarked about 40 years ago:

> I believe that there is no philosophical high road in science, with epistemological sign posts. No, we are in a jungle and find our way by trial and error, building our roads behind us as we proceed. (31)

Our men of science have had other physical limitations too. Vikram Ambalal Sarabhai (1919-1971) was a man of vision and dream for the country with infinite capacity for hard work. He knew how to identify youngmen for research in a copule of minutes. He knew too how to nurture them by giving eaqch jof them a life's chance of freedom. H.J. Bhaba (1909-1966) our bachelor scientist, painter, musician, dancer and having eye for beauty in what he saw talked of TIFR having a budget of 40,000 rupees with no firm structure on paper except that it was to engage itself

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in nuclear and high energy physics. The remarkable work done by this institute over the years is the envy of any nation anywhere in the world. He declared in 1963 that the National Institute of Sciences was a case of conceptual failure. It is, in fact, a case of functional failure for all elements that ought jto exist, did exist and do exist for the advancement of science and technology. It is simply a case where empty vessels makes too much noise and then biting critism by those who were involved actively in the same game or he tried his best to carry as many scientists as possible with him when it came to the type of reactor we should construct in this county. Baba had the diverse discussion under contol but Professor K.S. Krishnan clinched the issue by quoting a story:

> Yesterday I mentioned the instance of a man who had joined for research the great mathematician Jacobi who was the brother of the great orientalist. The yund man has been with him for several months without having started any research work. When the teacher asked him about it, he said, "I have not yet read all the earlier literature on this subject". Then the professor turned to him and said, "Dear man, if your father had waited to see all the girls before marrying one, where would you be " ? I would like you to make a start somewhere. You can get on with the scientific problems and proceed".(31)

S.N. Bose (1894-1974) whose name is very much intimately associated with Albert Einstein wrote in

1924 a four page paper on "Planik's Law and Light Quantum Hypothesis". He cut short Asutosh Mukherjee, the Vice Chancellor of his University when he complained abut the incompetence of the teachers of mathematics when he said that none of their students had solved a mathematical problem whichhe has been setting for the last three years by saying that the problem itself was wrongly set. One of the fundamental particles, Boson, is named after him. He did not possess a doctorate degree. He approached Einstein for recommendation to the position of professorship. Einstein did oblige but said, " Are not the works you have done in science more than sufficient for a certificate"? His papers on "Unified Theory" (1953-55) appeared when Einstein had his day. These papers did not receive sufficient attention because of lack of interest in this area of research; and possibly new interactions of nuclear physics and particle physics were managed to provide the missing link between gravitation and electromagnetism". One also needs God fathers as well as publicity officers to go up the hierarchy. M.N. Saha (1893-1956) is another legendary scientist whose parents were too poor even to support his school education. Regarding the role jof demonstration in the teaching of physics, he quoted a thousand year sanskrit text (Rasendra-Chintamani).

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> I have heard much from the lip of savants. I have seen many (formulae) well established in scriptures, but I am not recording any which I have not done myself .....I am only recording those fearlessly which I have carried out before anyelders with my own hands. They are alone to be regarded as real teachers who can show by experiments what they teach. They are the deserving pupils, who, having learnt from their teachers can actively perform them and, improve upon them. The rest are mere stage actors. (31).

P.C. Ray, the father (Indian Chemistry), taught chemistry and not the chemistry syllabus of the Calcutta University to his students. He would humourously advise his students to burn text books, notes and digests etc. for they produce "parrot licensed ignoramuses". Let us now talk of C.V. Raman (1888-1970), one and only one indigenously produced nobel prize winner in physics. He also hated the use of textbooks as the sole tool of instruction. His work done at Calcutta and Bangalore is a long story. He was a grand old man of science for throughtout his life, he lived as a man of science. Unlike many, he left his lucrative ob of the Indian Accounts and Audit Service to join the physics department of the Calcutta University. He was very productive in accoustics but shifted to optics and physics of crystals. He and his collaborators established several laws connected with

scattering from 1922 to 1927. In 1927, Venkateswaran got green colour instead of blue when sunlight scattered on a highly purified sample of glycerine. He immediately saw a parallelism between Crompton effect and light (later to be called Raman effect). How much had he spent on his own equipment ? It was about two hundred rupee only. According to him, the "essence of science is independent thinking, hard work and not equipment". It should not be forgotten that scientists now work in teams whereas the philosophers do not. It is of interest to add that since the discovery of Raman effect, 1800 papers were published in this area. Using Raman effect, about 2500 different chemical compounds were investigated in respect of their composition, structure, molecular interaction, isomerism, polymerization, solvent effect, hydrogen bounding and metics of fast reactions. The laser proved an ideal source for further investigations in this area. When one talks of Raman effect, one is reminded of "stimulated Raman effect, Inverse Raman effect and Hyper Raman effect". With the passage of time, his enemies also grew. He became bitter especially in the last years of his life. He used to say that it is difficult to succeed in science without political support. To quote Raman:

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> I came here from Calcutta. Bangalore is a nice place and I thought there were people here who were interested in science. I wanted to make Bangalore the Centre of science in Asia. Then at the Institute of Science, they gave me hell. "You may be scientist, but youare no administrator," theysaid. They cut the grants and they have said that I had embezzled money.(31)

So, life is a dream which throws pies in the form of discoveries to the sky. They land down from there to the ground , not knowing who threw them where. He who catches a couple of them gives a general empirical as well as theoretical explanation. If turned successfully successful, he snatches knowledge from nature and thereby adds to the existing stock of knowledge. As already reiterated earlier, the verdict of science is not final. So the pie is thrown again in the sky. The game goes on. Apples continue to fall. Apple fell on Newton's head. He provided explanation for gravity. Apples now need no longer fall on Newton's head because of the work of Narlikar and others. Similarly, sky and the sea continue to look blue which Raman saw while sailing on ship. He came up with the explanation how the colour of light changed on scattering. Thus the scientists sees sense in nature and admires it by communicating it to us. (31). According to Einsten, "God does not play dice" Heisenberg retorted back by saying that it is not our business to tell God which game to play.

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off the tangent findings of interest

It appears that ideas in science sooner or later appear to reach an edge. Newton discovered the composition of light when he found measured dispersion inconsistent with Snell's law discovered earlier. The electric battery was conceived and developed when existing detectors of electric charges failed to behave in the context of Franklin's paradgm. Uranus did not behave as predicted mathematically. So this led to the discovery of Neptune; and, laterr on, that of Pluto. The small but persistent anomaly in the measured density of nitrogen led to the discovery of nobel gas, then considered non-reactive. The anomalous properties of conduction led to the motion of electron which acquired spin, later on, to explain the then existing anomalies observed in atomic spectre. Strong electrolytes like common salt and sulphuric acid contradicted the Theory of Electrolytic Dissociation right at the time of its origin in 1887 by Arrhenius, Chemists did not bother the least for they remained (strong electrolytes) anomalies for not less than thirty years. Physicists did not reject the quantum hypothesis when the laboratory value of the specific heat of hydrogen did not agree closely with the one obtained from quantum theory. They instead tried a subsidiary hypothesis assuming the existence of two states of hydrogen. This removed the anomaly. This

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is the way, the investigative way along which the hypotheses are set up, tested and reformulated (and acts combined) that an objective body of knowledge results. Let ut cite some more examples.

Galelio asserted that it is difficult for the water column to rise up above 32 feet because the very weight of its column breaks it. Two years later, Torrricelli hypothesized and related it to the existence of air pressure, a massive force which several centuries later was used by George Westinghouse for stopping the fast moving trainss. Jan Van Helmon, one of the very well known and highly respected scientists of the 17th century, while engaged in solving the mystery of life, left an interesting recipe for making mice; 'Take slightly soiled shirts, place them in a dim, quiet corner sprinkled with kernels of wheat and in twenty-one days, one would have mice. It turned out to be a highly efficient formula for making mice. Dr. Paul Ehrilick made 605 unsuccessful efforts before he could develop successfully Salvarasan for the treatment of syphilis. He named it the 606th formula. Howard Rogers studied unsuccessfully about five thousand chemical compounds before he could invent successfully, a new molecule for obtaining instant pictures. Another side light ! Despite confirming evidence, nobody took seriously the chance

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relationship verified empirically that the 'gestation period measured in days of animals ranging from rabbits into cows was a multiple of 22/7'. Father Spallanzani snatched truth from nature by 'dazzling experiments, close observation and insane patience. He obtained money for advanced work through cunning plots and falsehoolds. On the top of it, to avoid religious wrath, he became a priest. Michal Faraday, an illiterate scientist of Great Britain put his head inside the poles of electro-magnet for determining the effect of magnetism on human physiology. It was not a successful experiment. This led Zjeeman to determine the effect of magnetism on spectral lines. The line broadened. He increased the strength jof magnetism by drawing inspiration from Michael Faraday but no success. The reason was that he had a microscope of poor resolving power. He referred the photographs along with the data to the Royal Society of England. It was termed as a major discovery called the 'Zeeman' effect. He won a nobel prize for this discovery. Similar is the case with the discovery of Stoke's lines, anti-stokes lines and the Raman effect noticed in organic liquids and crystals (an other nobel prize for a Russian). If hypothesized still further, what about the same effect under low temperature physics? Again a nobel prize for a German scientist who left his doctoral work to win this prestigious award. As

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far back as 1826, a noted Russian metallurgist visualized and suggested a radically new way of using metal powders. In our times, it became the powder metallurgy industry which takes advantage of latest developments in physics, chemistry and engineering. It does away with melting, casting and machining. Thus was born the high pressure chemistry, a technological dream of significance. It thus becomes possible to control chemical reactions in terms of speed, velocity and synthesis of new compounds and materials and that too with pre-determined specifications. According to Max Planik, such happenings arise because of vivid intuitive as well as artistic imagination. Lastly, the main distiguishing characteristic of any thinker, scientist and for that matter inventor is his productivity over a long period. Much is at stake because it is not at all a matter of divinity, a single moment of insight and even luck, for scientists too live on "cheated inspiration and borrowed credit" as Keostler has put it. (21)

What applies to science also applies to engineering to a varying extent. But, generally speaking, the engineers are quite oblivious of the assumptions made by mathematicians and physicists in their theoretical derivations. For example, without

suffering any theoretical inconvenience, the engineers can draw a straight line on earth without defining it. They have to do so for they have to solve the practical problems. Metallurgists, for example, find information on the chemical composition, tensile properties or hardness of a given alloy inadequate. They do not feel dejected because they supplement this information by supplying its entire manufacturing history, for its varied utilization. In conclusion, all the above mentioned examples illustrate the theoretical as well as the practical difficulties with which scientists and technologists have to live with. They do not at all discard the complex problems straight away whch appear too opaque for them at the beginning. Instead, they reexamine them at depth and pose them in their solvable forms with a view to master the consequent difficulties gradually. (22)

Scientific thought as well as : Temper and Education

Scientific thought, if Piaget is true, develops during adolesence and goes right into adulthood. Its deveopment depends upon diverse aptitudes, career commitments, individual talents, preferences, habits and ways of viewing the same problem in diverse ways. The adolesent pupil lives in the world of possibilities

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and tests each one of them ass he deems fit. He tries one solution and then another until he is satisfied. He still goes forward in his thoughts and excperiments for, apart fron constant questioning, he visualizes the continual interplay between the hypothesis under test and the logical expectation stemming from it. Thought moves forward, backward and then again forward. In this process, mistakes are committed which, meaningful, are essential to the progress of scientific idea; and finally, to the development of science itsef. Thus, are, in fact, born discoveries out of confusion and erratic thinking which demand a sort of child's innocence to the point of absorption. It is preciselyfor this reason that the pursuit of successful science remains with the young people. "Humility", according to Linus Carl Pauling, "is jnot at all a statement of learning". A "goody-goody" attitude to a scientific finding is a danger for it leads anybody nowhere. Why ?. The finding is neither confirmed, doubted nor refuted. Kierkeygard goes a step further when he is attributed to have said somewhat as follows:

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> Knowledge is an attitude, a passion. Actually an illicit attitude. For the compulsion to know is a mania - for it produces a character out of balance. It is not at all true that scientist goes after truth. It goes after him. It is something, he suffers from. "D.N.A." you know, is like Mida's gold. Everyone who touches it gets mad. (23)

Neither the position in the hierarchy nor the majority view makes one right in science. In other words, the principle of authority is completely discarded in the field of science. In an agricultural dominant society, the old man is reckoned as the very wise man of the village. In the industrial society, on the other hand, his role has reached the dead end, that is, a sort of 'has been". Lysenko, a wicked, wretched and, at the same time, the top man of science in U.S.S.R. refused to see D.N.A. in the powder form because D.N.A. is an acid and acid is a liquid. It is again worth reflecting that biologists since 1953 put forward more mistaken ideas than their predecessors, all put together. some of their mistakes, essentially speaking turned out to be "Beauties". (23) Mistakes not only happen in science but must happen during the course of its growth. A man of science, when useful and productive, turns out tobe great despite the fact that he has at one time or an other has committed more mistakes than others. Is it not interesting to learn that initially research on

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conductors was, in fact, carried out on insulators. Professor Pettenkopper of Germany believed firmly that he could not suffer from cholera as he had not willed it. He took a couple of phials containing dead cholera germs especially collected for this purpose from Calcutta. He did not suffer from it because jhe had not willed so. The medical science was the gainer because the concept of immunity was born. Any scientific idea always remains under threat of survival permanently. It is like the handing of the sword jof Domacles on the scientist's head; and his finding, in case no distinction is made between the two i.e. scientist and his works.

Let us now close this discussion by a central message highly relevant for those youngmen who are fully occupied in scientific research.

Try this and then some one whispers - not quite yet right.

Jacques Monod, a French scientist who received his nobel prize just before his death was more humble when he said, "I am trying to understand".(23)

Scientific temper

It is difficult to define scientific temper. Its close cousin is "scientific attitude(s)". Let this

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term be not defined. Instead, let us quote jfrom a tinyvolume entitled "Education and the spirit of science", a document prepared by the Educational Policies Commission over 20 years ago.

> In the modern world, the approach of
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> rational inquiry -- the mode of though which underlies science and technology -- is spreading rapidly and, in the process, is changing the world in profound ways .... The spirit of rational inquiry, driven by a belief in its efficacy and by restless curiosity, is .... commonly called the spirit of science.
>
> The term science is accurate but inadequate. It does not do justice to the fact that this mode of thought is relatedd also to questions men usually ask and answer for reasons which they think are totally nonscientific .... religious, aesthetic, humanistic, literary. the spirt of science infuses many forms of scholarship besides science itself.
>
> This statement attempts to define the spirit of science and to relate it to eduction. We believe that a greater awareness of that spirit would lead educators to assign to it a larger and more explicit place among the manygoals of education.
>
> The world wide pursuit and spread of science and technology are commonly recognized. Thee is less recognition that the alues and modes of thought which underlie science and technology also are becoming pervasive in the world. Yet these values and associated modes of thought may in the long run be more important to mankind and to education than the visible fruits of scientific and technological pursuits.

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....science and technology jon the one hand arouse the expectation of a better way of life, give promise of material satisfactions, and hold forth greater responsibilities for the development of human potentialities. They give rise to a genuine optimism and excitement. But they also give rise jto anxiety ------ to a gnawing apprehension of man's alleged loss of personal freedom, of certitude, of psychological security, of identity.

.....aware of the apprehensions aroused by the penetration of the scientific spirit, we conclude that the hopes it offers so greatly outweigh the drawbacks as to justify a major recommendation that a general worldwide fostering of the spirit of science is wise. This conclusion has implications for American foreign policy.

Recommendations

The schools should help to realize the greater opportunities which the development of science has made apparent in the world. They can do this by promoting understanding of the values on which scienc may fully exemplify all these values, they characterize the enterprise of science as a whole.

1. Longing to know and to understand.

2. Questioning of all things.

3. Search for data and their meaning.

4. Demand for verification.

5. Respect for logic.

6. Consideration of premises.

7. Consideration of consequences.

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> ......these values .... are part and parcel of any true education. These are characteristic not only of what is commonly called science, but more basically of rational thought -------- and that applies not only in science, but in every area of life. What jis being advocated here is not the production of more physicists, biologists or mathematicians, but development of persons whose approach to life as a whole is that of a person who thinks ------- a rational person. The characteristics of this mode jof thought merit consideration in greater detail..... To communicate to us its values should, therefore, be among the principal goals of education in our own and every other country. (24)

Science is not at all a single dimensional activity. Wheras the path of investigation is puzzling, the essence of the process from the beginning to the end is to control the probability of doubt by having a look at the problems which may lie in the shade. This is the function of experts, preferably, the interdisciplinary ones, and not that of the prime minister of the country. God should save him from too many experts. Our first prime minister, Pt. J.L. Nehru, brought out country on the scientific and industrial maps of the world. He has to be understood contextually in the light of circumstances prevailing at that time. The growth of scientifc temper among our people is supported by a legislative measure jtoo. In a thought provoking article on "Nehru and Scientific temper", Sailendra Nath Ghosh is very

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critical of Nehru when he says, "Pt. Nehru hailed the heavy industries as the temples of modern India which were sited in the forest areas." In turn, these temples went a long way in destroying the forests.(25). So a problem has arisen where personal gain was subordinated to social gain which, in turn, is yet to be further subordinated to environmental gain. The trouble with our experts, largely speaking, is that they lack first hand experience, possess a lot of text book knowledge and vomit out quite a few impractical ideas like the geography scholar of the yesteryears (26). They suffer from verbal diarrohea and groupism etc. Moreover, they are free from any accountability because their thinking is indicative rather than definitive in character. So scientific temper is the first casuality in our hierarchical set up or relations. Our clerical system of eduction hardly supports this hypothesized construct.

Education

Considering the size of the country, it is a vast enterprise. It touches almost every aspect of our lives. Like the grandeur of theriver "Ganges", it is a flow of ideas and practices. As we go distant

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into our past, our country happens to be a rare country where love of learning had an early origin. Superficially speaking, education is an easy subject to understannd. The more it is grasped, the more complex, it becomes. So, our futuristic system of education will evolve from that we we have or say, we do not have. We should use "hypotheses setting and testing sort of philosophy" while tackling our problems. In other words, we ought to be empirical minded here. Our children should build up their own small mountains of learning on which they stand; and thereby have clear and clearer view of what they are becoming. There is a little hope for this to happen in the distant future. We hardly examine our grooves and reflect on professional services to be rendered to children. We hardly relate our moves to what is happening ; and what ought to happen in our education, say, in our style of schooling and the ongoing pattern of teacher training and educational administration. Like the Greeks, we have failed to refurbish our age old "paideia", a sort of mutual play leading to the development of mature, enlightened individuals, using our available resources to the best of our abilities and skills. We suffer abundantly from tendencies of escapism. This type of exercise is essential to carry out from time to time because it costs nothing.

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problems are solvable if theyare not imaginary ones in nature. We have an organized confusion in our educational system. A few steps forward as well as backward hardly matter for the central core of this confusion, like the central core of the atom, is too hard to crack. Each one of us is helpless, if not hopeless, in the business of education. Let us ract to the serious concern of an ordinary parent like Norma Louis of Bombay for her eight year old's tasks at school in the wake of the National Educational Policy of 1986. To quote her:

> Our daughter is a little over eight years jold. She has entered the 5th standard this year. She has 33 text books and note books that we have just finished labelling.
>
> We wish to make no commet except praying that God may help our child and other little childen like her in this country. Also that, God may forgive us all for this cruelty to them.(28).

The physical and mental condition of our growig child is worse than a railway porter. Without commentig further for the former's pie is yet in the sky. In other words, it is now a matter of taking quantum jumps (leaps) in cognition within the context of where we find ourselves at this historic moment. Mao-Tse-Tung talked of three leaps in cognition. Except M.K. Gandhi, R.N. Tagore and Sri Aurobindo who were not professional educators, we did not have the

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benefit of personalities such as Charles Spearman, A.S. Neill, P.E. Vernon, John Deway, J.S. Bruner, David Ausubel, B.F.Skinner, L.S. Vygotsky and Jean P;iaget in this country. Their works have hardly touched the psychological structure of our various school subjects. To know means to transform the wotld/and, in our case, it means transforming our schools jin every possible way. Educational questions, like epistemological questions as shown by Piaget, must be anweredd experimentally. For example, can a pupil learn on his own while left alone?. He is a bad master who loads the donkey to a kill. Each problematique has to be rubbed on all sides. Likely result ? A windfall of ideas, strategies and insights. "Style is the ultimate morality of mind - exclusive privilege of the experts", said A.N.Whithead. In our view, students must feel for a style as they grow. On the front of educational research, our performance is hardly flattering to anybody. Lastly, in this educational war, we have no choice but to win. If e think, we cannot. We have to rethink and retry.

Concluding statement

So a journey on the creative road is a risky business. Hence, care and caution. Science is dynamic, contextual, processual, historical and

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dialectical too. It also disciplines one imagination without colour, knowledge of facts is, of course, necessary but not sufficient. It has to be tampered with "desire to know" and follow up the hypothesized ideas right up to their logical ends. The cultivation of science as well as technology and poverty do not go together. Hence, its highest importance, largely speaking, in all affairs of the state and individual. Hence , we need scientists of vision and every expanding imagination. The works of Roger Bacon took centuries to be understood. These works predicted all the likely scientific disoveries likely to be made within the next 800 years or so. How did he do it ? He, therefore, through his own efforts acquired the first and knowledge about the entire natural kingdom. He lived on the diet of bread and water. It is not difficult for a man of science to acquire wealth. If he dies, he will kinder himself from the great experiments in the pursuit of knowledge. he was a man of magnificent understanding when he posed the real problem facing us.

> I believe that humanity shall accept as an axiom for its conduct the principle for which I have laid down my life - the right to investigate. It is the credo of free men - the opportunity to try, the privilege to err, the cowage to experiment anew.

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> We scientists of the human spirit shall experiment, experiment, over experiment. Through centuries of trial and error, though agonies of research. ...Let us experiment with laws and customs, with money systems and government, until we chart the one true course..... until we find the majesty of our proper orbit as the planets have found there ..... And then at last, we hall move all together in the harmony of our spheres under the great impulse of a single creation ... one unit one system and one design.

So, we salute to all those who have laid-down their lives for the advancement of knowledge and thereby added to our existing stock of knowledge. Our admiration to all those among them who have survived in the shadow of death at their places of work and finally, became the fatal victims of their ideas and discoveries.

12

DEVELOPMENTAL EPISTEMOLOGY
AND FUNDAMENTAL PROBLEMS
IN THE THEORY OF KNOWLEDGE

Rolando Gracía

Genetic epistemology or, if you prefer, development epistemology attempts to answer the most fundamental problems still pending in the theory of knowledge. Developmental epistemology has been considered, more often than not, as just as theory concerned with some aspects of the development of conceptual thinking. This would mean that it has to do with child psychology, with learning theory, but not with the "real" problems that one finds in textbooks on the theory of knowledge. In the huge contemporary literature on the philosophy of science, developmental epistemology is very seldom presented as a comprehensive theory that may provide a truly alternative view on the foundation of scientific knowledge. It is for this reason that we are going to undertake the discussion of one part of the theory of knowledge that has been in many ways at the centre of a rather intensive polemic in the philosophy of science during most of

the century. Our aim will be to show how genetic epistemology fits into this discussion and how its findings disqualify in a conclusive manner prevalent views on the foundation of science. In order to do that, we shall be obliged to review some of the fundamental problems that philosophers of science tried to answer during the first decades of this century. We shall make a quick survey of those positions that have provided a sort of "official version" of what science is about. My apologies to the audience for dealing too quickly and therefore too superficially with a well-known and dense period in the contemporary history of studies on the foundation of science.

I am going to put, arbitrarily, the beginning of this story in the two schools that started in the twenties: the school of Berlin led by Hans Reichenbach, and the school of Vienna, with Schlick Neurath, Carnap, and others. I do this for one simple reason. Most of the Anglo-Saxon Philosophy

of science is still, by and large, a consequance of the type of discussions that were centred at these two schools. They dominated philosophy of science for at least two to four decades. They are still quite alive. If not explicity, be cause in philosophical discussions you find rarely now someone who will actually maintain these positions as they were- but in general, implicitly they are in the mind of large numbers of working scientists. History is never simple, and anybody who attempts to trace back the origins of any philosophical school will find himself submerged in a complex net work of many roads. Some of them going far back, quite a few merging with each other, still others deviating very much from the main direction but being linked by secondary connecting roads to the main trunk. We annot enter into this sort of analysis concerning the antecedents of the Vienna school or the Berlin schools. In a first approximation, however, you [illegible]

may agree that we may single out three ingredients that made up the core of the theory that emerged from these schools. They are : a) the views of Ernest Mach, concerning physics and, in general, the empirical sciences; b) the views of Henri Poincare, concerning the role of mathematics in physics; c) the revolution in logic started by Free and culminating in the Whitehead-Russell Principia Mathematica.

What they took from Mach was mainly his insistence on verifiability as a criterion for meaningfulness. When the young Mach got rid of his Kantian credo on the a priori elements in the foundation of knowledge he tried to show that all knowledge could finally be reduced to an analysis of sensations. Concept building should be firmly anchored on the content of sensations. With this in mind, Mach made a review of the history of mechanics and produced a masterpiece, a real classic. His brilliant criticism of Newtonian mechanics still stands in many respects. We only need to

mention Einstein's indebtedness to what he and everybody else after him called the Mach's principle. Mach's "Mechanics" is a fascinating revision of the history of this branch of physics. We can show today its many historical pitfalls and the weakness of its epistemological foundation. But it made a great impact particularly at a time when physics suffered a succession of spectacular revolutions which shook the most basic concepts about the physical world.

What the neopositivists of Vienna and Berlin found lacking in Mach were two things: first, any account of the role played by mathematics in physics; second; any indication of how to handle certain terms that played an essential role in physical theory and that could not be directly linked to observables. Here comes Poincare. As is well-known, Poincare introduced what later on was called the Conventionality Thesis. For him, the laws of mechanics are only conventions, although-he insists-not arbitrary conventions. They are conventions having an experimental origin. Experiments led the founders of science to adopt them. In this line of thought, the merit of Poincare was to show that in addition to terms that could be directly related to observations, science utilises theoretical terms and that these theoretical terms are expressed in mathematical language. The

main role of mathematics would then be to serve as an instrument for the introduction of theoretical terms. This is the second component of the Vienna and Berlin schools.

A third component comes from the tremendous revolution in logic of the Freze-Whitehead-Russell school. They tried to show- and they were convinced that they had shown-that in fact mathematics can be reduced to mathematical logic. Then, theoretical terms finally can be expressed in the language of mathematical logic. In this line of thought, mathematical logic was finally the tool used, particularly by the Vienna school, to express what scientific theories were.

With these tools, the picture at which they arrived was a picture that is known today by philosophers of science as the "standard view". Putman has called it "the received view" and this is a sort of coined expression that is being used by many of the contemporary philosophers of science. What is essential in this view ? In an extremely condensed and rough version of it, we could say that the standard view maintains that a scientific theory, in order

to deserve this name, should finally be expressed as some sort of axiomatic system. The degree of formalisation of these systems may vary very widely, but the structure of the system ought to be about the same, having the following elements: a) a basic vocabulary with three different kinds of terms, namely, logical terms, observational terms and theoretical terms; b) axioms that could establish the interrelations among the non-logical terms; c) rules of inference to allow for deductions from the axioms. In so far as the defenders of this view stick to the verifiability theory of meaning, the empirical data- the observables- are the raw material of the system. The observational vocabulary is the core. Everything else should be expressed in terms of this vocabulary. The logical part of the system was just reduced to express the rules of the game, the internal rules of the language that is being used to express the theory.

It was soon realised that it was necessary to add a fourth element in order to attach the system

to the ground: the correspondence rules. They were introduced to perform three quite different functions, although sometimes mixed together. First, a correspondence rule defines the theoretical terms. Second, they (the correspondence rules) determine the cognitive content of the theoretical terms, in the sense that a content [illegible] related to experience by means of the verifiability principle. Third, - a point which is sometime overlooked-- these correspondence rules specify once and for all the admissible types of experiments by means of which the theory is attached to reality.

This is in a nutshell the standard view. It started withna theory of science, as a theory of scientific theory. Scientific theories, so it was held, should work this way. Then the whole school developed in such a way that this sort of a scheme became also the standard explanation for all knowledge It became not only a theory of science but also a a theory of cognitive significance, of cognitive

meaning. Anything that we say that has any cognitive meaning must have some way or another an implicit scheme of that sort. If we use terms that are not directly related to experience and observation, we must have some correspondence rules that link what we say with experience. If not, we are in metaphysics and, as is well-known, the aim of this school was to kill metaphysics.

But they went even further. This positivistic school also developed a theory of language which went far beyond the theory of science. Language, for them, consists of observation sentences whose only non-logical terms are observation terms, and certain assertions use "theoretical" terms, explicitly definable in terms of observational terms. In this way, to be consistent, they had to develop a theory of how human beings acquire language. Thus, it was held that we initially acquire language through denotation: pointing, pointing to sense data, pointing to objects. And everything else should follow by definition, starting with this denotation that is the basic stone in language building.

This to me is an extremely important point that has not been sufficiently emphasised by the critics of the neo-positivistic schoo. Neo-positivists were obliged to build up a theory of language of the sort we referred to above. And they were obliged to do so because after all language was for them the element that provided the rules of the game within the whole theory. Without a theory of language the whole structure would collapse. And the theory of language, to be consistent with their position, had to be of the type of crude empirism we have just mentioned. This being so, it would be enoughtto demolish their theory of language acquisition, to demolish the whole theory. We are not going to do that, however, because we prefer to follow the historical way taken by the theory itself.

The theory started having difficulties, some of them indeed very serious. The first one had to do with the correspondence rules. It was thought that correspondence rules were definitions, direct definitio
It was Rudolf Carnap, the most outstanding exponent of the doctrine in its purest form, who realised that very simple terms used in common language, and quite

essential in science, could not be directly defined on the basis of correspondence rules.

The example he used, and that became the standard example for this sort of analysis, was "fragility". What does it mean that a given object is fragile? In accordance with the doctrine of the school it would suffice to provide correspondence rules for the expression "x is fragile" in terms of observables. We could establish, for instance, the equivalence between:

"x is fragile" (1)

and:

"at any time, if x is struck at that time,
then x will break at that time". (2)

In fact, all disposition terms, that is, terms like "fragile" expressing dispositional properties would be defined in the same way: "if you do this and this, then such and such an event will take place". But here the school was caught in its own trap. The reason is as follows. The logic used by the school was, as we have mentioned above, the Frege-Whitehead-Russell logic. In this logic, the conditional:

"if..... then...."

has an extensional interpretation according to which any conditional statement of this form is true whenever the antecedent is false. This means that the expression (2) is true of any object x which has never struck, and that in this case the expression (1) is also true. In other words, an object x which was never struck would be, by definition, fragile. But this is not the meaning we attach to the word fragile. Therefore the intended definition has failed.

I am not going to dwell any longer on this example that became a classic in this field, nor on the various attempts made to patch up the holes. Carnap himself proposed to replace the above definition by a set of partial definitions. This works in the case of "fragile" but it does not work in the case of other theoretical terms. This situation led to two kinds of developments that had serious consequences for the doctrine.

In the first place it was realised that not only the definition of theoretical terms but also the scientific laws, were conditional statements of a particular type called counterfactuals (or

subjunctive conditionals) and that the logic of the counterfactual conditional presented serious problems. It was thought that modal logic might solve the problem, but it did not help much. The idea gradually emerged that the extensional interpretation of conditionals had to be given up. The great progress made by intensional logic in the last two decades may be attributed, at least in part, to this situation. The second kind of development had to do with the very possibility of establishing direct links between the theoretical terms of the theory and some observables. Here again, the idea had to be given up and replaced by a much milder version of empiricism. There is not direct empirical interpretation of each one of the non-logical terms introduced in a scientific theory. It is the theory as a whole that could be given an empirical interpretat The theoretical terms acquire empirical meaning through

the empirical meaning attached to the theory, and not vice-versa. When you make an experiment you are testing a theory not a term within it. So the correspondence rules do not function at all the way it was thought.

But this was not the end of the difficulties. There were many others. I shall mention only one that plays a fundamental role in the position taken by developmental epistemology vis-a-vis empiricist theories of knwoeldge.

One of the main problems that remains in the official view of scientific theories refers to the concept of "directly observable". Whether you believe that you have direct definitions of theoretical terms in terms of observables, or that you provide empirical meaning to the theory as a whole and not to each single term, in all cases you end up with the concept of direct observations.

Of course defenders of the schools we are referring to were ready to accept that, whatever the definition of observable adopted, it was very difficult to draw a line between observables and non-observables. A property inferred from the measurement taken by an instrument may be considered as an observable by a physicist, whereas a more strict philosopher would reserve the term observable for properties that are directly perceived by the senses. Here there is already a problem: is it possible to make a distinction between observation terms and theoretical terms ? The answer was clearly negative but there is a more serious problem. Let us assume that we draw the line somewhere. Is it possible to maintain that there are atleast some observation terms, i.e. some terms that could be taken as directly observable in an absolute sense ? The idea that the answer to this question was also negative, i.e that all so-called "direct observations" involve some sort of construction by the observer, emerged very slowly. We shall come back to this question in order to show that genetic epistemology has provided a

definite answer to this problem, an answer that for the first time places suchna philosophical question in an experimental context.

We shall stop, at this point, the analysis of the internal difficulties of this view of science. We shall ask ourselves a more general question. Assume that in fact all serious questions have been answered. What is then the status of this theory of scientific theories? Do scientists work this way? Well, as you know, if you look into any presentation of scientific theories, the amount of axiomatisation is very small. You find partial aximatisations with varying degrees of formalisation. Moreover you reach axiomatisation at a very mature level of a science. You know that even in Newton's Mechanics there are still serious disagreements about the proper way of axiomatising it. So, the official view has not reflected the way scientific theories work. Much less, still, the way scientists work.

The most clear-cut answer to this objection was given by Hans Reichenbach. Science, he would say

is produced in a rather chaotic way. A theory of science should not attempt to explain how scientific theories are built, how they come out of the mind of scientists. Its task should rather be to justify, to establish on firm grounds the claims of the theory. Both objectives are quite different. In his book "Experience and Prediction" (1938) Reichenbach introduced a special terminology to refer to them. The first task belongs to what he calls "context of discovery"; the second, to the "context of justification". The former is the job of historians, sociologists and psychologists. It does not belong, according to Reichenbach, to the theory of science. Philosophy of science is only concerned with the latter.

Once the role of the philosopher of science is confined to the context of justification, the methodology to be used follows as a simple corollary. He has to divorce the claims of a theory from the process through which it was

arrived at. In order to do that he would have to rebuild the theory on a "rational basis". His task is therefore to proceed to a "rational (logical) reconstruction of science".

With this addition, we see that the final picture of the official view is a rebuilding of a theory resting on three pillars that represent three clear-cut dichotomies : a) the dichotomy between logical sentences (analytic: the rules of language) and empirical sentences (synthetic: based on observables); b) the dichotomy between observation terms and theoretical terms; and c) the dichotomy between discovery and justification. Let us now refer to the thrid one. Towards the end of the fifties and the beginning of the sixties, the idea started to grow that an adequate anlysis of theories would not consist in a rational reconstruction; that you cannot analyse a theory independently of the way in which this theory has been formulated; and that it is within the context of building up the theories that you

could discover, first, the real meaning of the theory and, second, the ways inwhich you are going to justify, it. So the position held by Reichenbach was rejected.

Perhaps the most influential of the contemporary philosophers and historians who have stood up against the standard view, and probably the most well-known of them, is Kuhn. With his theory of scientific revolutions, Kuhn started a revolution which still goes on. His main contention is that the history of science indicates that scientific change is fundamentally revolutionary. There is no continuous growth of science. Science grows by jumps. Science has periods of "internal equilibrium" so to speak; and then at a certain moment it jumps, it undergoes a revolution. It is during these revolutions that you get the real progress of science. Now, the defines scientific revolutions as those non-cumulative developmental episodes in whichan older paradigm is replaced in whole or in part by an incompatible new one. As everybody knows, paradigms for him are accepted examples of actual scientific practice. These examples include law

theory, application and instrumentation together. They provide models from which spring particular coherent traditions of scientific research. The idea is that in periods of quasi-equilibrium you have a sort of standard practice of science that is accepted by the scientific community, and that science develops inside it. This is what he calls normal science. Normal science, i.e. most of the science which is found in everyday practice, is developed within the paradigm, within an accepted framework. This framework provides the accepted practices, from experimental practices to concept building. Those who solve problems inside this paradigm are, according to Kuhn, simply solving puzzles within an accepted theory. They are "puzzle-solvers". Puzzles or queries are particular problems inside the system. They do not question the system.

Here we find an important point that Kuhn emphasises a lot. Within a given theory if you have a problem and you do not solve it, it is not the theory that is

blamed: it is the researcher who should be blamed. It is a personal failure not a failure of the theory. And this is normal in science. However, if you look for solutions to a specific problem and fail, and everybody else fails for a long time, a point will be reached after which it is not anymore a puzzle: it becomes a real problem, it becomes a crisis. At a certain moment a revolution will have to start in order to solve it. The ancient paradigm collapses.

So, the main contention of Kuhn's theory is that people generally practice normal science, except in various specific moments, which are the critical moments in the history of science, when the whole science enters into a crisis and has to jump into another level of analysis. Now, the problem that he was asked to answer is how the choice is made? And the answer given by Kuhn is very central to our problem because it is practically the only alternative left when you stay in sociology of knowledge or in a

certain kind of a psychology of knowledge. The answer he provides in one of the latest papers he has published on this subject is as follows: "In particular, confronted with the problem of theory-choice, the structure of my response runs roughly as follows: take a *group* of the ablest available people withthe most appropriate motivation; train them in some science and in the specialities relevant to the choice at hand; imbue them with the value system, the ideology, current in their discipline (and to a great extent in other scientific fields as well); and, finally, *let them make the choice*.' If that technique does not account for scientific development as we know it, then no other will. There can be no set of rules of choice adquate to dictate desired *individual* behaviour in the concrete cases that scientists will met in the course of their careers. Whatever scientific progress may be, we must account for it by examining the nature of the scientific group, discovering what it values, what it tolerates, and what it disdains".

With this formulation it is not surprising that Kuhn be accused of "following the mob rule" in the sense that finally for him it is the majority of the community that would decide how the choice is made. He defends himself saying that this is not the case because scientists, as is shown by history, do not choose "just anything". And the fact that they do not choose just anything is part of the scientific attitude. Here the tries to establish a sort of a limit, to introduce a demarcation line, different from the well-known Popperian demarcation, in order to separate what would be an irrational choice from a rational one. I will not go into this interesting aspect of the Popper versus Kuhn polemic.

Kuhn's attitude has been called by Popper "a dangerous attitude for science". He calls it dangerous for two reasons: a) for his appeal to history, sociology and psychology; and b) for his concept of a progress made by jumps.

Popper gets really upset by Kuhn's reference to the disciplines quoted above. In this respect he says: "I cannot conclude without pointing out that to me the idea

of turning for enlightement concerning the aims of science, and its possible progress, to sociology or to psychology (or, as Pearce Williams recommends, to the history of science) is surprising and disappointing.

In fact, compared with physics, sociology and psychology are riddled with fashions, and with uncontrolled dogmas. The suggestion that we can find anything here like "objective, pure description" is clearly mistaken. Besides, how can the regress to these often spurious sciences help us in this particular difficulty? It is not sociological (or psychological, or historical) science to which you want to appeal in order to decide what amounts to the question What is science ? or what is, in fact, normal in science ?

In other words, for Popper, psychology, sociology and history are underdeveloped sciences, so to speak. They have not reached mautrity. How could they help in achieving the task that the most precise philosophy of science has not been able to achiev

Of course, this is an appreciation that could be easily answered and we shall do so further on.

The second Popperian objection against Kuhn is that, for Popper, what Kuhn calls "normal science" is only "mediocre science". He says in this connection: "In my view the "normal" scientist, as Kuhn describes him, is a person one ought to be sorry for. (According to Kuhn's views about the history of science, many great scientists must have been "normal"; yet since I do not feel sorry for them, I do not think that Kuhn's views can be quire right.) The "normal" scientist, in my view, has been taught badly. I believe, and so do many others, that all teaching on the University level (and if possible below) should be training and encouragement in critical thinking. The "normal" scientist, as described by Kuhn, has been badly taught. He has been taught in a dogmatic spirit: he is a victim of indoctrination. He has learned a technique which can be applied without asking for the reason why (especially in quantum mechanics). As a consequence, he has become what may be called an *applied scientist*,

in contradistinction to what I should call a pure scientist. He is, as Kuhn puts it, content to solve "puzzles". The choice of this term seems to indicate that Kuhn wishes to stress that it is not a really fundamental problem which the "normal" scientist is prepared to tackle: it is, rather, a routine problem, a problem of applying what one has learned: Kuhn describes it as a problem in which a dominant theory(which he calls a "paradigm") is applied".

So, extra ordinary science is for Popper the only science, and it has a continuous growth. He "proves" this by reference to the history of science. Kuhn answers that this is not the case and he also "proves" it by reference to the history of science. It seems therefore that everybody is now doing history of science in order to prove his point in philosophy of science. Philosophy of science and history of science have come together more than ever. But by looking into history, people get entirely different answers. This is an important point to which we shall

have to come back. Here I will only indicate that this introductory lecture does not permit me to review the extremely interesting polemic going on between people like Kuhn, Popper, Feyerabend, Lakatos and others. If we could go into it, we could draw very important lessons by looking into the type of arguments they provide; this will illuminate not so much the subject of the discussion (and I apologise for daring to make this statement) as the kind of arguments they are using to prove their points. This would be a lesson about epistemology as it is currently practiced by philosophy of science, and the shortcomings of some of their methods. But we should have to leave this analysis for another occasion.

We now leave, at this point, our general comments on what we have called the "standard view" of science and its evolution in the last decade or two. Let us now address ourselves to the main subject of this seminar. Within the context of the

panorama we have summarised, how does developmental epistemology fit into the other positions or rather into the type of analysis that has been made until now ? In other words, to put it bluntly: why developmental epistemology? Before trying to outline some of the answers that genetic epistemology has provided or that can be inferred from it, I will refer to our introductory comments. The basic idea of this lecture is to present genetic or developmental epistemology as a theory of knowledge in its broadest sense. In this respect we want to show that the role played by genetic psychology within the theory is not only quite relevant to the clarification of basic issues of the foundation of scientific knowledge, but it is in fact an inescapable way of doing so.

Let us start by picking up what seems to me to be the most important flaw in current positions in the philosophy of science. Every theory that tries to offeraan explanation of how science works and how scientific assertions are validated, offers in fact a

theory of validation but does not offer a theory of validation of the validation. What is the criteria by means of which some assertion or some theory is validated ? It is quite clear that the question is legitimate and that it should not be answered by making an infinite regress.

How could the theories of validation be validated ? In the schools we are criticising, there is no effort made by the authors to validate what they say. But there is something more serious than this. In general, all these theories refer to subjects, to human beings who are the subjects in the act of knowing. If you put together what explicitly or implicitly is being assumed in current theories of knowledge, you find all sorts contradictary assertions or assumptions about the actual subject who is doing science. In general, there is no indication of whether they speak about a "natural subject", i.e. any adult who happens to enter into science and therefore has a "natural way" of thinking or reasoning, refined by science by natural; or if they refer to a very ideal kind of subject

who could be the "man of science", a man who will get together with other colleagues in the community and have a special aptitude to take decisions and special attitudes about this. Now, they have to choose between the two assumptions. If they refer to an ideal subject, the question they have to answer is: what is the relation between this ideal subject and acutal subject, the scientist in everyday life? For outside the laboratory and outside the writing of specific scientific assertions, a scientist behaves like any other man and does not use special ways of expressing of "finding" things or events. On the other hand, if they refer to the natural subject actually behaves in the way they describe or assume it. In particular, empiricists often refer to how a subject learns, for instance, language, or learns this or that. And there is no empirical test or no empirical work to show that what they say is empirically true, is empirically verified. They, therefore, attribute to the subject, within an empirical theory, certain attributes, properties, ways of behaving that have not been subject to empiric verification. The justification

thus remains hanging on air. Therefore i

a justification withinthe system.

Developmental epistemology has clearly shown how to obtain an answer to the above problem. Paradoxically, Piaget, being essentially anti-empiricist, put the problem in such terms that the que question could be brought from the level of abstract formulations and speculative philosophy down to the experimental level. The door was thus opened for an empirical refutation of the empiricist theory of language and knowledge. The basis for this refutation consisted of showing simply that the process of knowledge does not take place, in the way described by the tenets of the neopositivistic schools, neither at the level of concept formulation in an individual nor, historically, at the sociogenetic level. And here genetic or developmental psychology was the toolmused in order to prove this epistemological point. The assertion we made at the beginning, in the sense that the findings of

developmental epistemology disqualify in a conclusive manner previous ideas on the foundation of science, finds here application. We believe that the monumental experimental work of the Geneva school has left no doubt that the tenets of the empiricist school can no longer be accepted.

This leads us directly to the second point we want to reformulate from a developmental perspective. We have already mentioned that both Kuhn and Popper resort to the history of science when they do not find a firm anchor for some of their assertions about how science actually works. However, from the standpoint of developmental epistemology, the use they make of the history of science as well as the use made by Kuhn of the psychology and sociology of knowledge- does not touch the epistemological problems: they touch only the surface of the behaviour of scientists in a scientific community.

We are nevertheless closer to Kuhn in at least two of the most important points he has made in his theory of scientific revolutions.

We even think that the case for each one of them could be made stronger than in Kuhn's presentation. The first point is concerned with what we may call the relationship between "Weltanschauung" and paradigms in science. I will briefly refer to the best historical example I know: the principle of inertia in the ancient world.

As you know, Aristotle did not accept it. For him, if a body is in motion, it is because there is a force somehow pushing this body. If the force does not act anymore, the body stops. The force produces the motion: if there is no force, there is no motion. The most explicit rejection of the idea of inertia I have found in Aristotle's text is in connection with his "Proof" that the vacuum does not exist. He first shows that a motion would not stop in the vacuum. This being obviously absurd for him, he concludes that there can be no vacuum.

In parallel to the great period of the Greeks, there was an impressive scientific development in China. In certain aspects the Chinese were ahead of the Greeks.

This is the case for the subject we are considering. The Chinese contemporaries of Democrito had already formulated the principle of inertia in the most preciso way: if you have a body in motion and no force is acting on it, the body will continue to move eternally. Two thousand years before Galileo, there is a Chinese text that enunciates a principle like this. And they add something that may hurt the intellectual pride of the Occidental World: "And this is as clear as the fact that a cow is not a horse".

How is it possible that two different communities, the Greek and the Chinese, both at a very high level of intellectual development, arrive at conceptions that are so different? How is it possible that one of them considers obvious what is absurd for the other? Moreover, how is it possible that we had to wait two thousand years in the occidental world to arrive at a principle that for the Chinese was as evident as the fact that a cow is not a horse ?

I think we can find an explanation for this

surprising historical fact if we look more deeply into the basic philosophy of the Aristotelians and that of their Chinese contemporaries. For a large section of the Greeks, in particular for the Ariostotelians, the world id static. Everything in the world is at rest unless it is forced to move and this can happen for two reasons only: either God is impressing the motion(such as the case of the stars for instance) or else, somebody forces the body to move. If we exclude the acts of God, which produce what Aristotle calls the "natural" motions, every other motion in the world is a "violent" motion, i.e. the result of violence exerted on the bodies. If nobody produces any violence on any material object, there will be no other motions in the world except those produced by God. Violence takes the bodies out of their natural

place. There is a natural order in the world with stones below, water above, air above the water and fire above the air. If I let a stone fall down to us, it will do so because it will search for its natural place. Once this place is reached, the body will stop and will remain at rest. Within this conception, within this Weltanschauung, the Greeks did not need to explain rest, because rest is the natural state for everything in the universe. On the other hand they had to expalin motion and they had to find the cause of it. The cause is a force, i.e. a violence exerted on the body. When the violence, the force ceases, the motion will stop unless the body is out of its natural place because, under these circumstances, the body will take a direct motion what will bring it down or up to its natural place.

The philosophical conception of the Chinese was quite different. For the Chinese, the world is a becoming, it is a continuous process of change.

The world is evolving all the time and everything within it is also evolving. Therefore motion does not need to be explained. What they need to explain is rest. You need force to keep something at rest, to prevent the natural becoming of that something in its development within the universe. If there is no force, the body will contine its natural development.

We only now need to recall the fate of the principle of inertia in the Occidental World. After it was "discovered" during the period of Galileo, Descartes and Newton, the principle was alternatively considered as rather absurd and difficult to accept, as entirely evident and needing no explanation and, much later, as a principle that is neither evident, nor right, nor wrong, nor absurd, but rather a regulatory principle within a certain structure of a theory of Mechanics. This proves beyond any doubt that the acceptability of a principle, such as the principle of inertia, is linked in a very fundamental way to the whole conception of the world or, at least,

to the conception of the particular branch of science to which it belongs, this in turn being linked to a particular society in a particular period of its history.

Let us now turn to the second point with which we find ourselves in agreement with Kuhn, although we shall differ in the epistemological interpretation of the facts. We agree with Kuhn's conception of history in that it is not a continuous process but one that goes by jumps. Kuhn explains these jumps in the history of science by an accumulation of doubts about the theory which, at a certain moment, take the form of a crisis. From the start point of developmental epistemology, however, we believe that the jumps obey to much more fundamental principles out of which this evolution by jumps becomes more or less a corollary. In order to show what I mean by this, I am obliged to make a brief

incursion into some aspects of Piagetian theory that have been widely misunderstood. They are related to the role of structuralism in Piaget's conception of epistemology. Right from the start of developmental epistemology, it is not structures which characterise the evolution, but functions. The motor of evolution no matter where, are functional properties, not structural properties.

As is well known one of the basic tenets of Piaget's position is continuity between organic and cognitive processes, based on the fact that both processes involve an adaptation of the organism to its environment. More precisely, Piaget has frequently emphasised the fact that there is a global adaptation of living organisms to their enviornment and that biological and intellectual developments are only particular cases of it.

How does this adaptation takes place? Piaget insists that, in both cases, adaptation involves

an equilibrium between assimilation and accomodation. The nature of the equilibrium is clearly different in one case and in the other and it leads to quite different kinds of structures, but there is a functional continuity between organic and intellectual assimilations. There is, therefore, a process of organic structuralisation (if we may use this English neologism) as there is a process of cognitive structuralisation. No one can ignore the specificity of structures at each level. The mechanisms, the functional factors involved are characteristic of evolution, not the structural properties in each domain. Thus, the emphasis of the theory is on the verb" to structure"(now rare in English language) rather than on the noun "structure". In this active process of structuring- both at the organic level and at the cognitive level- the structures arrived at do not form a continuum. They come one

after the other through a discontinuous process. The system - either organic or cognitive- jumps, so to speak, from one structure to another at discrete intervals. This is perhaps the best known of all Piagetian findings and I will not elaborate on this any further. The point I will now make is that what was found by Piaget at the cognitive level, and what was more or less evident at the biological level, is becomin clear in almost every branch of science [illegible] today Let us be a little more specific. What is becoming clear are the following facts: a) that a sort of assimilation takes place in all open systems interacting with their environment; b) that this is so even at the purely physical level; c) that this assimilation process is a builder of structures; d) that these structures are just stages of quasi-equilibrium that will be disrupted through new assimilation processes; and e) that after disruption, the system will reorganise

itself to reach another level of self organisation, i.e. a new structure. In order to show what is meant by this, I am going to give an extremely simple physical example. I have some misgivings in using this kind of an example because sometimes when I have done it, it has been taken as if I intended to bring physics to explain the cognitive system. My objective is just the opposite: I want to show that what was discovered in the cognitive system also works at the physical level. In other wrods, that physics is much closer to bhological and cognitive processes than we though some years ago.

The system I am going to consider is the simplest one I know that belongs to the category of what I have called "structure builders". The system is as follows: Let us take two cylinders one inside the other with a space in between; let us put

a liquid between them- just water- and close it so that there are no surface waves on top. Let us now have a rotation of the two cylinders but at different speeds: one rotates inside the other but one goes quicker (for instance the outer one goes quicker than the inner one). You put in the water some particles of aluminium or something like that, so that by illuminating them you can see the motion of the liquid. When the difference in rotation of the two cylinders is small, the liquid that will start moving by friction will acquire a quite uniform motion of rotation. You will see circular stream lines spread throughout the liquid in a completely uniform distribution. You now increase the difference between the two rotations (for instance, you keep the speed of rotation of the inner cylinder fixed and you increase that of the outer cylinder). At the beginning you will see only small

oscillations of the stream lines. At a certain moment, however, the motion will be disturbed as if the liquid was upset and did not know exactly how to behave ! But very soon you will find that some patterns will appear in the stream lines: some of them will get closer together and will indicate a motion of the fluid with an non-homogeneous distribution of the velocity along the vertical. [illegible] there will be jet streams distributed at regular intervals. If you now increase still more the difference of speed between the cylinders, the stream lines will again oscillate but after a certain threshold the circles of motion will be disrupted and you will get a waving motion of the particles. You may now play with the difference in speed between the cylinders. You increase in a continuous way and then keep it fixed, you increase again and keep it fixed and so on; you will see jumps in the structure of the stream lines: the

the number of waves along the path will increase by discrete intervals and, at a certain moment, the waves that were completely symmetric will start tilting and become deformed in an altogether characteristic asymmetric way. If you increase the difference in speed still more, you will cross a threshold after which the waves disappear and the motion becomes turbulent.

How could we interpret this rather surprising experiment ? In the first place, let us emphasise that the whole system is homogeneous : the cylinders are homogeneous, the distribution of angular speed homogeneous, the fluid is homogeneous. However, will get self-organisation of the motion of the which will acquire structures. These structur by jumps. The second point is, that from physical point of view, the process coul described in the following way : the

rotating at a higher speed than the inner one, will impress a momentum to the fluid that must be obsorbed by the fluid. If we use Piagetian language, we could say that the fluid has to assimilate the changes in momentum that come from its environment(the cylinders). In order to do that, the motion will acquire at each moment the type of structure that will be more efficient in doing this assimilation(that is in transporting momentum from the outer cylinder to the inner one). What is characteristic of the process is that by increasing the difference in angular speed in a continuous way, the change in structure is not continuous. There will be intefvals where the structure remains about the same and oscillates around quasi-equilibrium position If a certain threshold is crossed, then the fluid reorganises itself and acquires a new structure [illegible] about the same and oscillates around quasi-equilibrium

that is more efficient in absorbing the momentum from the outer cylinder and transporting it to the inner cylinder. Here we see clearly in an extremely simple physical example a process where assimilation, accommodation and equilibrium between them take place in a manner which has striking similarities with the processes described by Piaget at the cognitive level.

It was the merit of Ilya Prigogine and his co-workers in Brussels to discover that all open systems at the physical, physico-chemical and biological levels, behave in this way, and that the thermodynamics of open systems could explain why they behave like that. The theory of dissipative systems has been extended to many domains. Jean Perroux, in France, has tried to apply this theory to explain the economic behaviour of a society. He has shown that, countrary to what has been claimed by all classic economic theories, the behaviour

of a society adapts itself to certain environmental processes and that the society itself to maintain self-envisaged structure. Changes in structure take place when the boundary conditions in the system change. But these structural changes do not proceed in a continuous way; there are jumps from one level of organisation to another level of self-organisation in a characteristic discrete manner.

Piaget's theory that adaptation of an organism to its environment involves two functional factors and an equilibrium between them, and that it takes place at both the organic and the intellectual level, appears therefore to be the most general law of evolution at all levels for all systems. The old scholastic dictum: "natura non facit saltus" is being entirely demolished in this way. On the other hand, the Marxist dictum of a characteristic process of evolution through which

which there is a transformation of quantity into quality- a rather vague formula not very well-founded in Marxist literature- may be re-interpreted in this way and provided with a very solid foundation.

Let us now, after this long digression, come back to the subject we left pending. The findings of the Piagetian school, after more than half a century of experimental work, have proved in a conclusive manner that the intellectual evolution of a child proceeds in the way indicated above: a succession of stages of quasi-equilibrium between assimilation and accomodation at different levels. But what about the socio-genesis of knowledge? Does science evolve as a continuous process in the way Popper would claim, or does it proceed by jumps in the way pointed out by Kuhn? Recent work carried out at the Geneva school provides strong support for the Kuhnian thesis.

However, once again, we agree with Kuhn's proposals, but we do not agree with Kuhn's explanations. The findings to which we refer do show that there is a striking parallelism in the evolution of cognitive systems between the level of the child's intellectual developments and the level of the evolution of science. Moreover- and this is much more important they show a most surprising identity of the mechanisms at work at both levels. I will indicate what I mean by this by providing just one example taken from a research that has covered the history of mathematics and the history of physics.

Piaget found that in the development of genetic concepts in the child there were three quite characteristic stages that he called: "infra-figural", "interfigural", and "trans-figural". At the first level, the child is only able to consider internal

within a figure; at the second level the figure can be submerged in a system of relations, in a certain context; at the third level the child is able to consider transofmations of figures from a much more general point of view that will allow him to combine transformations. To be more specific let us take an example which shows the diference between the first and the second level. A child at the first level is able to draw perpendicular lines but he may not have the concept of horizontali and verticality. If he is asked to draw the trees on the slope of a mountain, he will draw the trees perpendicular to the slope and not in a vertical direction. To understand "vertical" and "horizonta which means that the child has to submerge a relati in a system of reference external to the figure itself- we have to wait until the intellectual development of the child reaches the second level.

the inter-figural. Now if we turn our attention to the history of geometry as a science, we may also distinguish three quite characteristic periods: the period dominated by Greek geometry, which is a kind of a science concerned with the properties of the figures considered in isolation from each other. We have to wait until the 19th century to see geometric properties conceived as invariants within a system of transformations. Quite a few decades after the birth of projective geometry, Klein offers a quite different perspectiv of geometry by showing that the systems of transformations used by projective geometry could be explained by considering algebraic structures within which the system of transformations can be inferred from the structure. The theory of groups thus provides an entirely different level of

conceptual development in the evolution of geometry. The three periods in the history of geometry may be therefore shown to coincide with the three periods in the development of geometric concepts in the child. Moreover an analysis which cannot be reproduced here shows that this is not just a simple analogy but that in both cases the mechanism that gives rise to the passage from one level to the next are common to both the history of science and the children's development, in spite of the fact that the actual content of the geometric concepts at the scientific level and at the children level are entirely different.

You may doubt whether we can prove historically what we have said above. My aim is not to convince you that this is so. The claim is rather that we can put research into the history of science into clear-cut epistemological terms and

it becomes a rather objective type of research to find out whether or not history proceeds in that way. We therefore claim that developmental epistemology has provided tools of research by means of which all epistemological problems could be formulated in such a way that we could get clear-cut answers through experimental work: experimental work with children and experimental work with that marvellous, huge experiment provided by the history of mankind.

To close this introductory lecture, let us get back to our starting point. We claim that developmental epistemology is not only an epistemological school that provides some answers about how children's conceptual and theoretical systems evolve. It is a theory that attempts to provide a solid foundation for the whole theory of knowledge and thereby an explanation of the growth

of scientific knowledge. It therefore stands up as an alternative philosophy of science that for the first time could be subject to experimental test.

Piaget and science education

Historical perspective

The publication of Jean Jacques Rousseau's Emile in 1762 introduced a revolutionary idea into educational philosophy, namely that sound pedagogy should be based upon a knowledge of child development. This idea has now become a fundamental principle of educational practice and pedagogical styles often follow new discoveries or theories in the field of child development. A case in point is the influence which Freudian psychology had upon progressive education in the 1920's, '30's, and '40's. While educational styles are probably dictated by many other sociocultural factors, such styles clearly owe a good deal to contemporary innovations in the psychology of the child.

It is in the context of this historical relationship between pedagogy and child development, that the current interest in the work of Jean Piaget must be seen and evaluated. No one doubts any longer that Piaget is to developmental psychology what Freud is to psychiatry, namely the giant in the field.

Indeed, it will take decades for us to assimilate and apply the vast body of information he and his colleagues have gathered in close to fifty years of studying the development of children's thinking. And here lies the danger and the reason I began my remarks with an historical allusion. Piaget's work adds to but does not supplant the insights of other child development workers. In trying to adapt educational practice according to the contributions provided by Piaget, we must not forget the lessons that innovators suchnas Montessori, Dewey, and Freud had to teach. Our zeal to be modern should not blind us to all that is valuable from the past.

With these few historical and cautionary remarks out of the way we can turn to the issue at hand; namely, some implications of Piaget's work and theory for science education. As I said, it will take decades to digest all of Piaget's contribution, so that all I can do here is to illustrate some of the new paths along which Piaget's work will take us. These new paths lead in the direction of: (a) the sequencing of science activities

(b) the methods of science instruction, and (c) the contents of science teaching. Let us now take up each of these problems in turn with the reservation that I am suggesting directions only and that we have only begun to tap the wealth that lies in Piaget's books and articles.

Sequencing science activities

One of the dominant themes of Piaget's developmental psychology of intelligence is that the mind develops in a sequence of stages that is related to age. While the sequence remains the same for all children, the rate at which particular children pass through the stages will depend upon genetic endowment as well as sociocultural circumstances. Piaget has described four major stages each of which, for heuristic purposes, can be described with regard to the major cognitive task it poses for the child.

The first, or sensorimotor stage, lasts from birth to about the age of two. During this period the infant's principal task is to construct a world of permanent objects so as to arrive at a conception of things which continue to exist even when they are not present to his senses. This stage

might be described as dominated by a "search for conservation". At the next (preoperational) stage, usually ages 2 to 6 or 7, the child's major task is to master the symbolic or representational function. It is during this period that the child acquires language, discovers symbolic play, and experiences his first dreams. At this stage, the child might be said to be involved in " a search for representation".

At about the age of 6 or 7, the child enters the concrete operational stage, which lasts until about the age of 11 or 12. During this period, the young person has to master the interrelationship of classes,relations, and members, and he does this with respect to things and with the aid of syllogistic reasoning. The concrete operational stage is, therefore, one in which the young person is engaged in "a search for relations". During the last or final operational stage(usually ages 12 to 15) the young adolescent's major task is to conquer thought. Formal operational structures enable him to take his own thinking as an object and think about thought, about contrary fact conditions, and about ideal

situations. In a word, it makes possible theoretical and philosophical speculations and might be called the stage in which the young person is engaged in "search for comprehension".

What have these stages to teach us about the sequencing of science activities for children? A great deal, it seems to me. First of all, these stages nicely parallel the stages that characterize the development of any science, namely: observation(sensorimotor period or the search for representation); naming and labelling (preoperational period of the search for representation); formal classification and quantification(concrete operational period or the search for relations) and controlled experimentation and theory building (formal operational period or the search for comprehension). While it is not necessarily true that children will learn science best if it is taught on the model of the growth of thought and of science, it is at least a possibility worth exploring.

It seems to me that Piaget's work implies that science educational ought to begin with teaching children the fine art of observation. Actually children are often far better at this than we are because our concepts blind us to concrete realities. Or repeated experience has for adults taken much of the interest and curiosity out of many of nature's mysteries. It is not enough, however, simply to have animals in the room, or to have children look at leaves and squirrels on nature walks. What children need to be taught is how to focus their observation, how to look for similarities and differences among natural elements, among leaves, animals, grasses, sounds, and shells. Instruction in observation cannot be hurried and year or two of science teaching ought to be devoted to instruction in observation.

Thereafter children might proceed to collect specimens that they can sort, label, and classify. The nature of physical and biological classifications might well be described and discussed.

My impression is that we often take the child'. ability to classify for granted and do not spend enough time talking about the criteria of classification can be introduced at the same time as children weigh, measure, and sort the specimens that they work with. In general, the wider the range of materials children have to work with, the more solid will be their grounding in the rudiments of science.

From the standpoint of mental development, instruction in controlled experimentation probably should generally not be introduced until adolescence when young people can deal with multiple simultaneous variations. By and large the concrete operations of children are not sufficient to grasp the intricacies of multiple variable experiments. Obviously this is not a hard and fast rule; bright children may be able to appreciate experimental procedures by the age of ten. For the average child, however, experimental science might well be delayed until adolescence when the young person's mental abilities are sufficiently mature to cope with holding some factors constant while others are systematically varied.

Perhaps it is unnecessary to stress to science teachers the importance of training children in observation and classification before they are introduced to experimentation. At the college level, however, I am impressed at how few students are trained to be good observers before they are trained to be good experimenters. Experimentation is a precision tool, but its effectiveness depends upon the skill, experience, and openness of the experimenter. If a youngster is so set on the experimental variables that he misses some of the novel and significant side effects of his experiment, then he is not a good experimenter in the best and most general sense of the term.

Methods of science instruction

I have probably stepped on some people's toes by now and I am probably about to step on some more. That is inevitable, I suppose, when one presumes to discuss subjects outside his own field expertise. What I have to say about methods of science instruction may therefore sound quite naive! My only defense is

that sometimes naivete can be refreshing and strike at a problem that experts have been bypassing as too touchy and sensitive. Let me plunge in again.

What impress me about American education, at all levels, is its extreme verbalism. Enter any classroom a above the kindergarten level and most of what you see are books and more books. Our national preoccupation with reading, currently embodied in the Office of Education's Right to Read Program, practically amounts to an obsession. So preoccupied are we with reading that any youngster who has a reading problem soon develops an emotional problem about it which ends up being far worse than the reading handicap itself.

Now while I do not wish to downplay the importance of language arts in grade school. I do want to say that I believe language has been given exaggerated importance in the elementary school curriculum. Young people who are successful in our schools are remarkably adept at the verbal level and become increasingly so as they move through high school and College. The problem is that their language facility

is often divorced from reality and experience, and often amounts to empty verbalism. I would not be surprised if at least some of our problems with young people today derive from the discrepancy between their language, sophistication and their experimental naivete.

In this connection, Piaget's work suggests that language and thought are different systems that develop at different rates. The linguistic system appears to be relatively compete by the age of seven or eight when all the major elements of generative grammar are present. Growth in language thereafter appe appears largely in vocabulary and proficiency in such skills as reading, writing, and spelling. Thought, on the other hand, is much more gradual in its development, as I described earlier, and the mental systems for thinking are not complete until the middle of adolescense when mental ability at last catches up with verbal facility.

From an educational standpoint, it seems to me that these considerations support Dewey's contention that there should be more emphasis on doing and less on talking during the elementary school years, particular

particularly in the teaching of science. I hope I don't offend anyone if I say that teachers, including college professors like myself, simply talk too much. If we spent less time talking and more time showing children how to observe, classify, measure, then young people would get more out of it. We also put too much reliance on books and published materials and too litle faith on our own resources and in our ingenuity. Science can be taught with such a wide variety of readily available material that we really don't need prepackaged programs in order to teach science well. Science is first and foremost an attitude of curiosity and that is what the use of everyday materials promotes. Packaged materials lead children to believe that science always comes Christmaswrapped.

Please understand, I am not pooh-poohing all prepackaged science programs. I am, for example, particularly impressed with the work of Rebert Karplus at Berkeley who is trying to get away from the empty verbalism that is present in so much of our teaching. Many of the Karplus programs are

first rate. The problem with packaged programs, as I see it, is that they often make for rigidity and hamper the teacher's initiative. On the other hand, if teachers are given the freedom to us the materials in their own way, then packaged programs can be useful. They are even more useful if supplanted with everyday living materials.

Now I suppose I should say something about the so-called discovery method. To the extent that the discovery method suggests that children should be active in learning, then certainly one can endorse it. If it means that a child must discover by himself that which others have discovered for him, it may be a futile and unrewarding enterprise. The whole point of discoveries is that once they are made everyone can share in them without having to repeat the process of discovery. Life is too short for each child to redicover all of science. Likewise, to argue that children should be active does not mean that they should be active all the time. Some science facts have to be learned by rote and without

complete understanding. Learning things that we are not inclined to learn is an important part of education as it is an important part of life. Unfortunately, not everything we need to learn is especially intersting and children and teachers must accept that fact.

Educational content

One of the domains in which Piaget's work is likely to have its greatest impact is in the domain of the content of science and mathematics teaching. This is true because Piaget's work often reveals a previously unknown and complex substructure to concepts that were previously taught simply or even taken completely for granted. To illustrate the implications of some of Piaget's findings for teaching particular concepts, I have selected Piaget's work on number and upon identity. The work on identity should be of particular interest to those concerned with teaching in the biological sciences.

First, with respect to number, Piaget undertook his investigations in order to resolve a long-standing controversy between mathematicians and logicians. As you know, the mathematicians, following Peano, argued that mathematics was built upon several simple postulates

which were relational in character. The whole number system could, in Peano's view, be derived from the notions of a number and its successor (n+1). Logicians, following Russell and Whitehead, argued that number was not derived from a relation but rather that it constituted a class, namely, the class of all classes. The number six, for example is the class of all classes of things taken six at a time.

Piaget sought to resolve this controversy by determining how number concepts are arrived at by children. He undertook a series of novel investigations into children's ideas about number, classes, and relations. What he discovered was the child's understanding of classes, of relations, and of numbers all appear at the same time. Indeed, Piaget found that it was the child's ability to coordinate the idea of classes with the idea of relations that led to a true conception of number.

To make Piaget's discovery concrete, letme describe two of the studies concerned with classification and with seriation. In the classification study,

Piaget presented children (aged 4 to 7) with a box in which there were 20 while and 7 brown wooden beads. He asked the child whether there were more whitbe than brown leads and then whether there were more white than wooden beads. It was not until the age of six or seven that most children could solve the latter problem and could recognize that there were more wooden beads because only some of the beads were white while all of the beads were wooden.

In the domain of relations, Piaget presented 4 to 7 years-old childrenw with a set of size-graded sticks. The child's task was to arrange the set to form a sort of staircase withnthe shortest to the longest stick arranged in a regular order. Piaget found that many five-year-old children could construct suchna series. When, however, he presented the children withna second set of sticks, intermediary in size to the first, and asked the children to insert this new set into the staircase formed with the other set, children of five years for the most part could

not solve the problem. It was only at the age of 6-7 that children could place the second set correctly within the readymade series; i.e.. place an element 'b' between A which was smaller and B which bigger than b.

In both the class and the relation studies, the crucial task for the child was the discovery that one and the same element could be in two classes or in two relations at once. In the class concept study the children had to discover that a particular bead could be both white and wooden at the same time. Likewise in the seriation task, the solution rested upon the child's discovery that a particular element could, at one and the same time, be both longer and shorter than the elements on either side of it. In both instances the child resolved the problems by moving to a new level of abstraction wherein one and the same element could be doubly represented without conflict.

In Piaget's view, this is just what is required to attain the adult or true conception of number. The true conception of number is founded upon the concept of a unit. Now the unit concept is one which presupposes that the unit is both like every other

unit and different from every other unit in its order of enumeration. Every penny in a row of six is like every other as they are interchangeable. Their difference lies in the order in which they are counted or enumerated. In short, for the child, the concept of a unit or a number presupposes the same mental ability as that required to nest classes or to seriate relationships, namely, the ability to grasp that one and the same element can be represented in two different ways at the same time.

From an educational perspective, this findings has important implications. It means that the understanding of number develops hand-in-hand with the understanding of classification and seriation. Accordingly, practice in classification and in seriation might play a more dominant role than in children's preparation for instruction in This is already being done in some nursery and kindergartens but much more could br the materials for classification and r were available in greater quantity variety.

The second example of how Piaget's work might influence educational content comes from Piaget's work on identity. Actually, some of Piaget's earliest studie dealthwith this issue, to which he has recently returned after some forty years of concern with other matters. In the original studies, Piaget had children arrange a series of pictures (which resemble a set of frames from a comic strip) into the right order so that they would tell a story. Piaget found that young children had great difficulty with this task. One of the reasons was that they did not seem to recognize that it was the same character in each successive frame. The child's failure to understand the continuity of a sequence thus seemed to reflect his inability to detect the identity of the characters who participated in the sequence.

In more recent years, Piaget has pursued this issue with materials related to growth and aging. He and his colleagues (notably Gilbert Voyat) presented children with photographs of a plant at various stages

of growth. Although the children could recognize that adjacent photos were of the same plant they had trouble believing that the early photos in the series were of the same plant as they depicted in the last photos in the series. Again, the child's concept of growth was affected by his difficulty in grasping the notion of the plant's identity across transformation Clearly this finding has implications for biology teaching and suggests that, as a bare minimum, we know whether or not children understand the identity of plants or organisms across various transformations before we proceed to more complex topics.

These are but two fairly simple examples of the significance of Piaget's research for the content science teaching. Many more could be easily cited. As in the case of sequencing and methods discussed earlier, these are merely examples of the treasures Piaget has uncovered for us. Much of the

treasure remains to be mined. Lastly, in looking at children's minds through the new lenses Piaget has gained for us, we must not forget that children still have physical needs and are social beings. Lasting educational advances will be made only when our concern for the growth of the child&s intellect is tempered with consideration for his body and concern for his sense of self-esteem.

Improving Formal Reasoning:

A Comparison of Variables Training and Strategy Training

By

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Improving Formal Reasoning:
A Comparison of Variables Training and Strategy Training

Introduction

One of the reasoning strategies that an adolescent who has attained the formal level of reasoning can employ is called "controlling Variables".[1] The controlling variables strategy is used to design fair experiments, experiments where one variable is manipulated and all others are kept the same. For example, a fair experiment to find out if the material of the rod influences how much a rod bends would use rods of different material but equivalent length, cross section, etc.[1] Two methods for teaching adolescents the controlling variable strategy were compared to a no-training condition in this investigation. One method, Variables Training, was designed to help subjects correctly apply the controlling variables strategy to

new problems. The other method, the Strategy Training, was designed to help subjects acquire the controlling variables strategy. The no-training condition was called Tuning, following Cronbach and Snow(1977). We describe each condition and literature relevant to it in the sections that follow.

Variables Training

To teach subjects to apply the controlling strategy to new problems, we focused on changing their expectations about the variables in the experiment By expectations we mean beliefs about which variables influence the experimental outcome. Studies(e.g., Linn & Swiney, 1981) showing that some errors in applying the controlling variables strategy occur because subjects use expectation-based rules, motivated our investigation. Expectation-based rules emerge because, for any task, subjects expect that certain variables need to be considered. We call these the subject's expected variables. The variables

that the experimenter selects for a task, the experimenter's comprehensive variables, may differ from the subject's expected variables. Linn and Swiney (1981) found that subjects controlled their expected variables more frequently than other variables, and they performed as if the controlling variables strategy applied only to their expected variables. Our variables training was designed to alter these expectation-based rules.

Research Relevant to Variables Training

Piaget (1971, 1977) has focused researchers on content-free strategies rather than on expectation-based rules. In their original work, Inhelder and Piaget (1958) implied that formal reasoning would be universally acquired during adolescence. When confronted with evidence to the contrary, Piaget (1972) postulated that formal reasoning might be acquired only in One's area of expertise. Given that expectations are presumably most accurate in One's area

[illegible]. Given that expectations are presumably most accurate in one's area of expertise, perhaps Piaget anticipated that expectations would influence reasoning performance.

Piaget may have anticipated the role of expectations but he did not investigate them, nor did he suggest that instruction might explain their effects. Piaget was a genetic epistemologist-- he focused on the acquisition of content-free strategies, consistent with his theoretical focus on the child's system of logic rather than on the child's application of logic. We can distinguish between strategy acquisition, as described by Piaget, and strategy application which may be governed in part by expectation-based rules. This distinction is similar to the competence-performance distinction described by Flavell and Wohlwill (1964).

Research has revealed that reasoners use formal reasoning strategies inconsistently (Keating, 1980; Linn & Levine, 1978; Mortorano, 1977; Scardamalia, 1977). Inconsistency in formal reasoning performance could reflect both strategy acquisition and strategy application. Piaget (1971) referred to effects of task content, and therefore, by implication, effects due to expectations, as "resistances". He reports that resistances have an unpredictable effect on content-free strategy usage although the effect can often be explained after the fact. Our research suggests that effects of task content can be predicted (e.g., Linn & Swiney, 1981). We research in this study whether training can be designed to modify these effects.

Strategy Training

Errors on controlling variables tasks may occur because subjects lack understanding of the controlling variables strategy or fail to realize that the controlling variables strategy is required for the task. Strategy Training was intended to teach

subjects the controlling variables strategy.

Research Relevant to Strategy Training

Many instructional programs to encourage better reasoning about complex maths and science-related problems have been tried with limited success (see Levine & Linn, 1977; Linn, 1980a). Teaching new strategies has been much less successful than teaching new ways to use existing strategies. Piaget(quoted by Hall, 1970) has remarked that instruction in the content-free strategies characteristic of formal reasoning is useless. Many unsuccessful studies attest to this assertion (e.g., Levine & Linn, 1977; Linn, 1980b). In contrast, training procedures have taught subjects to control variables on a wider variety of problems (Linn, 1980a) or to apply proportional reasoning more consistently (Kurtz & Karplus, 1979). Of course, strategy

application cannot occur unless the strategy has been acquired. Instruction which combines training in strategies with training in applying strategies succeeds more consistently than either one by itself (e.g., Linn, 1980a, b; Kuhn & Angelev, 1976; Linn, Chen, & Thier, 1979).

Tuning

Subjects in our control condition received what Cronbach and Snow (1977) have referred to as "Tunning". In effect, Tuning is a form of instruction which helps subjects recognize when to use an available complex reasoning strategy. Tuning may increase strategy application, although it differs from the variables training which was also intended to increase strategy application. Examples of procedures which can be classified as tuning include: a) presentation of practice items, b) instructions which note the similarity between new items and familiar items, e.g., saying "These items involve

computation of proportions", c) instructions which specify what about the porblem is most important, e.g., saying, "In these items, first figure out what variable is being investigated then figure out which variables need to be kept the same". Tuning was, of course, present for all subjects in our study.

Research Relevant to Tuning

An example of tuning or teaching new applications of available strategies comes from a study by Stone and Day(1978). They administered three controlling variables tasks in counterbalanced order to the same subjects. The procedure included a variety of probing questions to alert subjects to the variables involved in the task. Probes asked, for example in Bending Rods, for subjects to select two rods which differed only in cross-section. Stone and Day found that a significant proportion of the subjects improved in their ability to control

variables from the first to the third task. The procedure used by Stone and Day (1978) resembled what Cronbach and Snow (1977) called tuning.

The Tuning in this study is similar to the procedure used by Stone and Day (1978) and consisted of practice items without feedback. We hypothesize that the practice items help subjects select the appropriate strategy for these tasks.

Methods

Design

We compared Variables Training, Strategy Training, and Tuning. As part of a forty-minute interview, all subjects received five controlling variables tasks in one of two counterbalanced orders. Variables Training and Strategy Training subjects received instruction for two of the five tasks. Tuning subjects received all five tasks without instruction.

Subjects

One hundred and eight 13 and 15 year olds in three different districts (30 per age per district)

participated. One third of the subjects received each treatment. Six subjects moved during the study, leaving a final sample of 174. The districts represented three socioeconomic status (SES) groups: upper middle class, middle class, and lower middle class. The upper middle class district was suburban: families owned their own homes and many older students drove their own cars to school. The middle class district was urban: families lived in single family dwellings, apartments, and condominiums. The lower middle class district was semirural: families lived in small single family dwellings, apartments, and condominiums, and many adults were employed in adjacent factories. Quality of the science programs in the three districts based on courses available and teaching materials employed correlated directly with SES.

Controlling Variables Tasks

The controlling variables taks had either naturalistic content(e.g., experiments to determine

what makes rods bend). Each task included some or all of the four questions as shown in Table 1. The four questions used were Constructing, Criticizing, Analyzing and Naming which are described after the variables for each task are presented.

Insert Table 1

Number and Type of Question
per Reasoning Task

	Question Type			
	Naming	Controlling		Analyzing
Reasoning Task		Constructing	Criticizing	
Training Tasks				
Springs	1	2	2	1
Runaround	0	2	2	0
Post Test Task				
Toothpaste	0	2	2	1
Bending Rods	1	3	2	1
Fishing	1	1	1	1

The variables for each of the five tasks are as follows:

1. Bending Rods, a laboratory task adapted from Inhelder and Piaget (1958) and described by Linn and Swiney(1981), allows investigation of the bendability of rods. The five variables are: the material of the rod, the thickness of the rod, the shape of the cross-section of the rod, the length of the rod, and the size of the weight hung from the rod.

2. Springs, a laboratory task described by Linn and Rice(1979), is parallel to Bending Rods, but subjects investigate the expansion of springs. Variables are: the material of the spring, the cross-section of the spring, the length of the spring, the thickness of the wire, and the weight hung from the spring.

3. Toothpaste is a naturalistic task where subjects investigate what makes the best toothpaste. The variables are: the presence or absence of fluoride, the flavor, the presence or absence of a dentist's recommendation, the cost, and the amount of advertisi

4. Fishing, a variation of the naturalistic task used by Pulos and Linn (1978), allows investigation of factors influencing the number of fish caught. The variables are: the type of bait(three possible), location(four possible), the presence of absence of a bobber, the type of reel(two possible), and the presence or absence of a radio.

5. Runaround is a naturalistic task about running speed. Variables are: running location, running surface, clothing worn, amount of sleep, diet, time of day when running, and type of shoes worn.

Controlling variables questions. The four questions in the controlling variables taks(constructing, Criticizing, Analyzing, and Naming) are described in this section. In the results, two questions, Constructing and Criticizing were combined to form a Controlling score, following previous research showing complete overlap of true scores for these questions(e.g., Linn & Rice, 1979; Linn, Pulos, & Gans, 1981). One question, Naming, measured the

subject's expected variables (e.g., Linn and Rice, 1979); the others measured reasoning about the controlling variables strategy.

1. In Constructing questions, subjects were asked to construct a controlled experiment for a particular variable and explain their response. For example, in Bending Rods, subjects were told "Do an experiment to show that thickness of the rod makes a difference in how far down the rod bends", and "Why did you do it that way?" Subjects passed if all variables except the variable under investigation were kept the same in two or more trials.

2. In Criticizing questions, subjects were asked to criticize the procedure for an uncontrolled experiment when not shown the results. Subjects passed if they identified uncontrolled variables.

3. In Analyzing questions, subjects were asked to criticize an experiment when shown the result but not told the procedure. For example, in Bending Rods, two rods painted different colors and made of different

of different materials were placed at unequal lengths in a wooden stand. Hanging equal weights on the rods, the experimenter demonstrated that the short rod bent more than the long rod and asked, "Is this a good experiment to prove that short rods bend more than long rods? Why?" and "Do you have any questions to ask about the experiment? Subjects passed if they indicated that some variable might be uncontrolled.

4. Naming measured the subject's expected variables. For example, in Bending Rods, the apparatus was presented and the interviewer asked, "Tell me what you think might make a difference in how far down these rods bend. What else ?" All variables in laboratory tasks were visually obvious. The Naming score was the number of variables named. For all tasks, in all conditions, after the Naming question, subjects were given a card listing the experimenter's comprehensive variables.

Instructional Conditions

Tuning consisted of performing all five controlling tasks with no additional information and no feedback, and was available to all subjects. The Variables Training and the Strategy Training each consisted of the tasks from Tuning plus a statement about how to control variables and four examples of how to control variables. Two examples came from Springs and two came from Runaround. These examples were in addition to questions asked to evaluate the trainings. In the training, order of examples was counterbalanced. In each example, two experiments were described, the subjects indicated which experiment was best, and the experimenter explained why one experiment was better than the other. The remaining three controlling variables tasks were administered in the same manner for Strategy Training and Variables Training as they were administered for Tuning.

Examples in Variables Training

The Variables Training examples encourage subjects to select the experimenter's comprehensive

variables. Previous studies (Linn & Swiney, 1981; Linn, Clement, & Pulos, Note 1) demonstrated that the subject's set of expected variables were often incomplete. In the _Variables Training_ the experimenter explained that the experimenter's comprehensive variables should all be selected.

Variables Training consisted of a general statement, four examples, and a repeat of the general statement. The general statement was: "The way to do these problems is that even if you don't think something makes a difference in the outcome of an experiment, it might be that it does make a difference. Like, in Springs, most people don't think that how often the springs are used is important, but if you use a spring a lot, it expands more easily than a spring that hasn't been used as much".

In each of the four examples, two experiments were described and the subject chose which was best. Then the experimenter explained the difference between the two experiments and told why one was better than the other. To illustrate, in Springs, the subject chose

from two experiments to investigate the cross-section of the spring. One experiment was fair and the other confounded material with cross-section. The experimenter explained the difference by saying "Okey, in the second experiment one spring was brass and the other was steel. Sometimes people think that material doesn't influence how far the springs expand so it may seem okay for one spring to be brass and the other steel. But really, material could make a difference. In fact, material does make a difference. Steel is hard to bend--- steel is used to make cars and to reinforce concrete because it is very strong; brass bends more easily than steel-- brass candlesticks might bend if dropped. So, the first experiment is better than the second".

Examples in Strategy Training

Strategy Training examples explained the controlling variables strategy. In previous studies, extensive Strategy Training has been moderately successful(e.g., Linn, 1980), although Stone and Day

(1976) found that a single statement of the strategy did not influence performance. In the present study, *Strategy Training* was more extensive than the training used by Stone and Day(1976) but less extensive than that used by Linn(1980).

Strategy Training consisted of a general statement, four examples, and a repeat of the general statement. The general statement was: "So, the way to do these experiments is to change only the thing that you are trying to find out about. You should keep everything else the same". There were four exampled. Just as for the Variables Training, each example compared two experiments and the subject said which was best. Then the experimenter explained which was best. In this example from Springs, two experiments about the cross-section or fatness of the springs were compared. The first experiment was fair and the second experiment confounded fatness with material. The experimenter's explanation was "As you recall, y to do these experiments is to change only

the thing that you are investigating, in this case, the fatness of the springs. You should keep everything else the same. Springs one and three are different fatness but they are also different material. So springs one and three are not good to compare because two things are different. Springs one and two are the same in every way except that they have different fatness so they are fine to compare to find out about the fatness of the spring".

Results

The performance of the subjects who received Strategy Training, Variables Training, and Tuning were compared on Controlling, Naming, and Analyzing. Recall that Controlling is the sum of Criticizing and Constructing. The effects of condition, sex, age, and SES were examined using analysis of variance (ANOVA) for the Naming and Controlling questions. Because there was only one Analyzing question for each task, and it was scored dichotomousl

the assumptions of ANOVA were not met. Hence, Chisquare tests were used to assess the results for the *Analyzing* questions.

Order and Interviewer Effects

There was no effect for task order on posttest performance. Analysis of variance performed on each of the final tasks by order revealed no significant effect on any task for the Springs-first or Runaround-first order of presentation (ANOVA for each task: Springs, F = 1.6; Runaround, F = 1; Toothpaste, F = 2.75; Bending Rods, F 1; Fishing, F 1; all values not significant at α =.05). Similarly, no effect for interviewer was found on a total score for all questions (ANOVA, F = 2.89, not significant at α = .05).

Controlling, Analyzing, and Naming

Controlling was responded to successfully between 45% and 88% of the time (Table 2). Reliability estimated by alpha was moderate but similar to previous findings (e.g., Linn & Rice, 1979).

TABLE 2

Means, Standard Deviations and Reliabilities of

Questions for each Condition

Question Controlling (Proportion Correct)	Strategies (N=59)		Variables (N=59)		Tuning (N=55)	
	Mean	Standard Deviations	Mean	Standard Deviations	Mean	Standard Deviations
Springs	.63	.34	.56	.379	.674	.278
Runaround	.64	.38	.68	.337	.612	.404
Toothpaste	.72	.38	.46	.397	.558	.375
Bending Rods	.88	.35	.80	.302	.747	.287
Fishing	.48	.48	.53	.494	.616	.437
Reliability (a)	.84		.78		.85	

Analyzing (Proportion Correct)	Strategies Mean	Variables Mean	Tuning Mean
Springs	.12	.17	.61
Toothpaste	.32	.17	.23
Bending Rods	.34	.28	.38
Fishing	.48	.50	.53
Reliability (a)	.29	.24	.52

Naming (Mean number of variables named)	Strategies		Variables		Tuning	
	Mean	Standard Deviations	Mean	Standard Deviations	Mean	Standard Deviations
Springs	2.8	1.0	2.5	1.2	2.6	1.2
Bending Rods	3.7	0.9	3.1	1.1	3.2	1.1
Fishing	1.6	0.9	1.8	0.9	2.6	1.2
Reliability (a)	.45		.68		.33	

Analyzing questions were solved successfully 30% of the time and as shown in Table 2, were more difficult than controlling. Reliability for analyzing was low but comparable to other studies for a scale of three items (e.g., Linn, Clement, & Pulos, Note 1).

On Naming, subjects mentioned about half of the experimenter's comprehensive variables on the average. In all interviews, Bending Rods followed Springs which may explain why more variables were named for the Bending Rods task than for the Springs task. Reliability for the *naming* scale was moderate for a test of three items.

Effects of Tuning

As suggested by Stone and Day's (1978) in identification of latent responders, tuning influences performance. Exposure to a series of tasks requiring the same strategy familiarizes subjects with the demands of the task and facilitates performance.

Springs and Bending Rods in this study are parallel tasks of about equal difficulty (Linn, Pulos, & Gans, 1981). Results for controlling demonstrate a strong effect for tuning: About 50% of tuned subjects were correct on Springs, but 80% were correct on Bending Rods, which always followed Springs. A matched-pair Wilcoxon statistic was significant beyond the .001 level.

Exposure to the tasks appears to facilitate performance; and effects for Strategy Training or Variables Training must be in addition to effects for Tuning.

Effects of Strategy Training and Variables Training

Performance on controlling on the first posttest, Toothpaste, was significantly related to training as shown in Table 3. Inspection of the mean percentage of correct responses on the Toothpaste task reveals that Strategy Training exceeded both Variables Training and the control condition. Thus, on the most direct measure of the training, the controlling score, Strategy Training was effective but the Variables Training was not better than the control condition.

Training also had no effect on analyzing. The Chi-square statistics comparing the proportions of subjects in each group who correctly analyzed each experiment were not significant for Toothpaste ($X^2 = 2.45$), Bending Rods ($X^2 = 1.3$), or Fishing ($X^2 \ 1.0$). The Chi-square for Springs ($X^2 = 38.3$, $p \ 0.5$) revealed that tuned subjects analyzed Springs better than the two groups of trained subjects (see means in Table 2). The training may have made subjects more accepting, and less analytical, of uncontrolled experiments, although some of the poor performance of trained subjects on analyzing can be attributed to a set of defective springs which were included in the set of materials for Strategy Training and Variables Training subjects.

For naming, neither Strategy Training nor Variables Training enhanced performance, although tuned subjects named significantly more variables than other subjects on the Fishing task. This may have resulted from additional time available to tuned subjects. Fishing was last in the interview and Strategy Training or Variables Training subjects may have been rushed.

Effects of Age, Sex, School and Interactions

There were no consistent effects for age, sex, or school and no consistent interactions across the five tasks. We report the isolated effects, which reached to p .01 level of significance for these variables, but offer no interpretation since the effects were not consistent.

On controlling, there were significant effects for age on Springs (F= 7.47, eta^2 = .008), and Runaround (F = 18.26, eta^2 = .02). There were significant effects for school on four of the five tasks: Springs (F= 7.19, eta^2 = .016), Runaround (F = 5.84, eta^2 = .01), Toothpaste (F = 6.81, eta^2 = .02), Fishing (F = 8.44, eta^2 = .01). Subjects in schools with high socioeconomic status (SES) performed best. Only one interaction was significant for controlling, many had F values less than one; the significant interaction was training condition by sex for Springs (F= 6.91, eta^2 = .015).

Discussion

Contrary to our anticipation of results, the Variables Training was no more effective than Tuning in altering expectations. Consistent with previous studies (e.g., Linn, 1980) the Strategy Training had a slight effect. Both the length and the content of the Variables Training could have contributed to its ineffectiveness.

We suggested that exposure to numerous controlling variables tasks might result in improved performance due to tuning. Consistent with the findings of Stone and Day (1978) the subjects improved by performing a series of controlling variables tasks. Improvement from Springs (administered first or second) to Bending Rods (administered fourth) was dramatic. Presumably, subjects became aware of which strategy to use by exposure to the tasks. It appears that most subjects *can* use the controlling strategy (since 80% are successful on Bending Rods and every subject responds to at least one *construction* question correctly), but that subjects do *not* always use the strategy.

The Variables Training focused on altering the subject's expected variables. Naming, found by Linn and Swiney (1981) to measure the subject's expected variables, was not altered by Variables Training. Previous studies (Linn & Swiney, 1981) to measure the subject's expected variables, was not altered by Variables Training. Previous studies (Linn & Swiney, 1981) indicate thate subjects will agree that a particular variable could be important even when they have not named it in the Naming question.

Variables Training was intended to make subjects aware of their tendency to ignore variables. It appears that subjects do not change their expected variables even when they are made aware that their expected variables could be incorrect.

In the Varibbles Training, our approach was to make subjects aware that their procedure for selecting expected variables might be incorrect. Since Variables Training was ineffective, it is tempting to suggest that subjects need evidence about how much variable influences the outcome and that this

evidence would change their expected variables. However, studies of the Pendulum (Linn, 1977; Pulos & Linn, 1978) suggest that evidence for a variable's role has only a small effect. Since neither evidence alone nor awareness of possible inaccuracies in expectations alone are sufficient, perhaps both together would be successful. Future studies will focus on these combinations.

The Strategy Training enhanced performance on the first posttest controlling question, but not on subsequent questions. The Strategy Training was not effective enough to insure that the strategy was applie to a variety of new tasks. Similar results in the Linn, Chen, and their (1979) study were attributed to inability to apply the acquired strategy. Studies by Linn (1980a, 1980b) and Kurtz and Karplus (1979) suggest that combinations of Strategy and Variables Training might be successful. Perhaps subjects need to acquire the strategy and learn to apply it. This should be a focus of future work.

Our study demonstrates that exposure to a series of controlling variables tasks (the Tuning

condition) improves performance on controlling questions. We presume that Tuning is effective because it helps subjects recognize which strategy, among those they have available, is appropriate for these tasks. Attempts to enhance strategy application by altering the subject's expected variables (in the Variables Training) did not have any effect beyong that of the Tuning. Attempts to enhance strategy acquisition by explaning the controlling variables strategy (in the Strategy Training) led to improved performance on the first posttest but not on subsequent posttests. Taken together, these findings suggest that successful interventions must address a variety of factors that limit reasoning performance, including factors related to strategy acquisition and those related to strategy application.

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Relationship Between Intellectual Development And Scientific Concepts

The Study

The present study aims at investigating the following purposes:

1. To see how concept formation takes place in children on certain selected science concepts.
2. To determine the mutual relationships, if any, as judged by the scores, among intelligence, intellectual development (Piagetian context), scientific concepts and achievement in science.
3. To determine difference, if any, between the top group and the bottom group in terms of variables included in this study.
4. To point out the main educational implications based upon the findings of the study.

Hypotheses to be Tested

It is proposed to test the following three Null hypotheses:

1. There are no changes in mean scores with grad on intellectual development, classification, conservation and porportion, selected science concepts(area, density, force and pressure) and achievement in science.

2. There are no mutual significant correlations as judged by the scores among scientific concepts, intelligence, intellectual development, and achievement in science.

3. There are no significant differences as judged by the scores between the top group and bottom group in terms of intellectual development, selected scientific concepts, and achievement in science.

Method of Procedure

Drawn out of a larger sample (N 220) the present sample comprised 100 pupils in all, i.e. 20 pupils each from grades V to IX of the local Demonstration Multipurpose School, Ajmer, within the age group 9+ to 13+. All of them came from the average socio-economic status and belonged to the urban areas.

The following tools were used:

1. Intelligence Test- Raven's Progressive Matrix.

The Standard Progressive Matrix was designed to cover the widest possible range of mental abilities and to be equally useful with persons of all ages, whatever their education, nationality or physical conditions

might be. This test also measures intell efficiency, a person develops a logical method of reasoning. The reliability was found to be 0.07 on $10\frac{1}{2}$ year students, 0.06 in case of $12\frac{1}{2}$ year students and 0.91 in case of adult students. From various results obtained there iscvery indication that perceptual tests are quite suitable for eliciting the higher intellectual functions and for assessing superior intellectual efficiency.

2. A battery of Three Piagetian Styled Tasks.

A preliminary run was given to several Piagetian styled tasks with a view to improve the statement of the tasks for presentation to pupils, using an overhead projector in a group situation. The three tasks measured abilities relevant to conservation of physical quantities, classification and construction of ratios. The tasks as used in the final form are state below:

Q 1. There are two friends Mr. Tall and Mr. Short. When measured by a row of paper clips placed one on top of the other were found 6 and 4 clips respectively. The height of Mr. Short was found to be

8 buttons. What will be the height of Mr. Tall in buttons ?

Q2. There is an aluminium sheet weighing 90 grams and an iron sheet weighing 120 grams. A circular piece of Aluminium sheet is cut off. The piece weighs 18 grams. If a piece of similar area is cutt of from the iron sheet what will be its weight ?

Q3.(a) There are two beakers A & B which are identical in shape and size. Liquid is then poured upto the same column in both the beakers. Will the volume of the liquid in both the beakers be the same of different ?

(b) Suppose I pour the liquid of beaker A into throuch C and the liquid of beaker B into a jar D. Will the trough and the jar have the same volume of liquid ?

(c) (After pouring the liquids) Now do they have the same volume of liquid ?

Q4. In a chart shown in different shapes in different colours we have to classify the objects according to similar shape, size and colour. Only

two objects (No. 2 and 12) satisfy this condition. In this the object number 2 and object No. 12 have the same shape (circular) and same size (radius) and the same colour (Black). Now classify these objects according to shape or size or colour taking one or two properties for each classification.

3. A battery of some selected Scientific concepts.

A questionnaire reproduced below was constructed to test the attainment of the following science concepts: area, density, force and pressure.

Q1. There are 12 cubes of same size arranged in two different ways.---- 6x2x1 and 3x2x2. Is the area of the table covered by the cubes the same, for arragement A as it is for arrangement B? Why ?

Q2. (1) There are two balls of plasticine of same size and weight. What will be the effect on the density if one ball is rolled out into sausage shape?

(2) A small piece is broken from one plasticine ball Will the density of a small piece removed from the whole be different from the density of plasticine of the larger remaining part ? Give reasons for your answer.

Q3. (1) Two identical piles of 12 cubes each are arranged as 2 x 2 x 3. Due to their weight does each pile push down with the same force on the table ?

(2) If the cubes in one pile were put on top of the other to make a column 1 x 2 x 6 would the force with which they push down on the table change ?

(3) Would the force of the pile pushing down on the table differ from the force of the column pushing down on the table Why ?
Write out your reasons for circling yes or no

Q 4. (1) 12 cubes exactly alike are arranged in 2 piles. Will the pressure on the table by the cubes in both the piles be the same ?

(2) Now each pile's made into 4 columns 1 x 4 x 3 . If a column of cubes in one pile is removed from the table will the pressure due to the remaining cubes be the same as the pressure on thetable, by the four columns of the cubes ?

(3) If two columns are removed leaving the arrangement as 1 x 2 x 3, is the pressure on the table under the pile of the two columns differ from the pressure on the table under the pile with 4 columns ? Why ? Write out reasons for your answers?

PRESENTATION OF SELECTED DATA

TABLE 1

Means and S.D.'s of the Piagetian Tasks and Some Physical Science Concepts

S.No.	Class	M/SD	Scheme of Thought(Piagetian tasks)			Some Physical Scientific Concepts			
			Conservation	Proportion	Classification	Area	Density	Force	Pressure
1.	V	M	0.75	0.20	3.75	0	0.25	1.45	2.00
		S.D.	0.51	0.35	1.83	-	0.48	0.58	0.31
2.	VI	M	1.90	0.95	7.20	0.20	1.85	2.30	2.15
		S.D.	0.99	0.52	1.76	1.25	0.71	0.93	0.35
3.	VII	M	1.65	1.05	9.30	0.40	2.60	2.10	2.00
		S.D.	0.78	0.42	2.30	0.65	1.12	0.93	0.31
4.	VIII	M	2.45	1.55	8.35	1.20	1.55	2.10	2.25
		S.D.	0.73	0.77	3.62	0.18	0.97	1.22	0.73
5.	IX	M.	2.40	1.75	9.50	1.60	2.05	3.05	2.65
		S.D.	1.20	0.76	4.09	0.31	0.78	1.60	0.79

TABLE 2

Correlation between Piagetian Tasks, Scientific Concepts Intelligence, & Achievement in Science

S.No.		Piagetian Tasks	Scientific Concepts	Intelligence	Achievement in Science
1.	Piagetian Tasks		* 0.4299		
2.	Scientific Concept				
3.	Intelligence	* 0.3344	* 0.3351		0.0761
4.	Achievement in Science	* 0.0864			

* Values Significant at.01level

TABLE 3

Means, S.D.'s and t-values Between Top Group and Bottom Group on Schemes of Thought, Some Physical Science Concepts and Achievement in Science

S.No.		Mean		Standard Deviation			
		[illegible] Group	Bottom Group	Top Group	Bottom Group	SED	t-value
1.	Conservation	2.44	0.56	1	1.202	0.3052	5.749*
2.	Proportion	1.68	1.56	0.925	0.687	0.3278	0.510
3.	Classification	8.28	6.68	4.003	3.802	1.1169	1.419
4.	Total Piagetian Tasks	12.88	8.80	4.137	4.833	1.2494	3.143*
5.	Some Selected Physical Science Concepts	8.04	5.32	2.660	1.666	0.6606	4.25*
6.	Achievement in Science	10.64	9.62	3.269	2.954	1.0725	1.138

* Values significant at .01 level

Main Findings

Within context of the present study the following conclusions can be drawn:

1. The mean scores on 3/4 of the scores of the scores of the normal children: conservation of liquid, proportion and classification indicates that these schemes are not established within the grades VI, VII, VIII, and IX. Similarly the mean scores on some slected scientific concepts: area, density, force and pressure reffects that the concept of area alone is attained only in the IX grade.

2. The means of the scheme of thought and some selected scientific concepts show increasing trends with grade.

3. There is noticed a dip in some of the grades on the problem of conservation, classification density, force and pressure. Hump effect is expected.

4. Significant correlation between intelligence, intellectual development and some selected scientific concepts was found.

5. There is a significant difference between

5. There is a significant difference between top group and bottom group (on basis of intelligence) in conservation, intellectual development and some selected scientific concepts.

Educational Implication

Jean Piaget has frequently said that he is little interested in children psychology and education etc. if his entire work is considered the following educational implications appear:

(i) He emphasizes the importance of activity in the growth of intelligence.

(ii) He explores in depth of growth of the child's thinking in relation to certain universals in the contents of human experiences such as the nature of objects, space, time, motion, chance, causality, moral responsibility and social awareness.

(iii) He proposes that certain underlying pervasive logicao-mathematical structures are found repeatedly in these diverse areas. Taos, Paris (Pleasure of discussion), Athens (the Socratic method) and Eldorado are the four models worthy of consideration while schematizing the use of materials and exercises

on the one hand and the type of social relationships on the other.

In the context of the present study, it can be safely considered that children should be allowed to handle abundantly the processes of thought rather than the products of thought for which the use of materials and experiments can be quire handy. The children alsonneed to be trained in handling, their erratic responses through exchange of ideas that is they need no longer remain egocentric in their intellectual behaviour. It is yet to be seen how far the deficiencies in Piagetian thought as manifested by children can be a handicap in mastering abstract concepts. Here Piaget provides a deeper model because it is through action as well as reflection on actions that the real knowledge is born in the mind of individual children.

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Defining the processes of science

Introduction

Science education at the precollege level in modern India is an intriguing blend of much of the best and some of the worst science teaching from all over the world. American teaching methods can be seen being applied to a basically British curriculum, using Russian-built equipment. In another area, a Russian-style program is taught by teachers trained in the British fashion, using equipment developed with American help. American, British, and Russian textbooks and library books are used indiscriminately. The objectives of teaching science have also been borrowed from a variety of sources. A study of lists of science teaching objectives in India reveals that each list can generally be divided into two categories. The majority of the objectives will be concerned with the science subject matter to be taught and mastered- the concepts, theories, and facts of science. But also included in among every list is the admonition that children must be taught the processes of science. This last objective is stated in a variety of ways: the scientific method, scientific thinking, critical thinking, reflective thought, or skills in problem solving.

Since several groups in India are working on new science content objectives, the Administration of the Regional College of Education, Bhubaneswar, assembled a committee to consider the definition of the process objective. The committee, of which I was a member, was charged with three responsibilities: (1) the definition of this objective; (2) the preparation of lesson plans and other instructional materials based on this objective; and (3) the development of methods to evaluate pupil growth toward it.

The following represents our attempt to define in operational terms the objective " to teach the processes of science". The various facets of this objective have been listed in a hierarchy which conforms roughly to the scheme of the Taxonomy of Educational Objectives. That is to say, the facets (indicated by the A,B,C, and 1,2,3 topics) are listed in ascending order from the simple to the complex. The ordering of these is not meant to suggest sequential teaching steps. Indeed, one of the primary reasons for the development of this list was to support our conviction that each of these facets can be taught as an isolated objective.

The process of science

A. Application of generalizations to new situations

1. Ability to deductively apply principles to specific experiences. Knowledge that has been memorized will be of little value to a student unless he can apply this knowledge to a new situation. This is sometimes called "going from the known to the unknown" since the student uses a general statement that he has already learned to explain an event that he has observed. A student who has learned certain principles of air pressure, for example, should be able to apply these generalizations to such problems as why it takes longer to boil water at high altitudes than it does at sea level, or why the use of a pressure cooker decreases the time necessary to cook food.

2. Ability tonextrapolate beyond given data. The nature of scientific investigation is such that generally only samples of evidence are available for use as the basis for decisions. Therefore, the student must learn to extend his thinking beyond the data (samples) that have been collected. He must be able not only to extend the trends of the data, but to recognize the limits to which he can safely do so.

B. Collection of data

1. Ability tonidentify a problem. One of the most difficult techniques in problem solving is identifying the problem. This is specially difficult for the immature student who, throughout his life, has been given statements of problems which he was to solve. However, it seems logical that, if a person is to learn how to solve problems for himself, he must first learn to identify exactly what the problem is. The student, as he participates in classroom activities or as he observes his surroundings outside the school, must learn to question the "why" of the phenomena he sees. He must recognize that he rarely knows the actual cause of these observed events, even though he knows an explanatio that seems satisfactory.

2. Ability to delimit the problem. After the proble has been identified in general terms, the student must then state it in such a way that he can proceed to work towards a solution. For example, such a question may be a simple, straightforward request for observable or measureable data, or it may be a hypothesis to be tested about the relation of certain phenomena to each other. Problems that cannot be stated with clear parameters and in the realm of observable physical pheno cannot be productive in science and are, therefore,

not consider to be a part of science. Before stating his problem, the student must recognize the limits of his ability to perform experiments, the limitations placed on him by the equipment that he has available, and the limitations of time. Moreover, he must be able to state his problem in such a way that it is possible to achieve an answer.

3. Skill in reading and understanding data in various forms. Professional scientists yearly produce tremendous amounts of data based on the observations that they have made. Since, in almost any problem area selected for investigation by the beginning science student, someone else will already have collected information, the student will find it necessary to read and understand these data. A great amount of skill is required if the student is to be able to do this, since these data will be found in a variety of forms. The student must learn to read and understand not only prose forms of writing, but he must also be able to profit from data recorded in charts, graphs, tables and in mathematical statements.

4. Ability to choose a course of action by determining what data are necessary for the solution of a problem. Before the student is able to solve the problem, he has identified, he must be able to select suitable

data from the many sources of information available to him. He must be able to analyse the problem to determine what types of data are necessary for its solution. Then he must have the skills necessary to locate and retrieve the proper data.

5. Ability to choose the best authority. The student is faced with a variety of materials from many, many sources. Some of these sources are more reliable than are others. The student must learn to judge the reliability of the source and to keep this in mind while accepting information.

C Analysis of data

1. Skill in formulating hypotheses. After a student has learned some of the basic concepts of a scientific discipline and has, from the data available to him, identified a problem that he wishes to solve, he must be able to formulate several possible hypotheses. The difficulty in stating hypotheses lies in the logical processes involved. It is necessary that the hypotheses proposed be consistent with other known data, even though these data may concern only slightly related phenomena. Further, the hypotheses must be closely related to the problem to be studied. Moreover, the hypotheses must lend themselves to the experimental methods available. It must be recognized that, unless the hypotheses are amenable to the methods available,

testing is impossible. Lastly, the hypoth
be stated in unambiguous terms.

2. Ability to organize lists of hypotheses. After a list of several possible hypotheses has been formulated, each student must be able to analyze his list. He must first be able to test each hypothesis ligically before the actual empirical evidence is collected. He must be able to place the various hypotheses in a rank order based on their probability of being true, so that a positive result from an early experiment will eliminate all other possibilities; or he must be able to rank his hypotheses so that one finding will supply information for subsequent experiments.

3. Understanding cause-and-effect relationships. The ability to determine whether or not two events are related to each other, particularly as cause and effect, is a basic element of scientific thinking. Superstitions, since they are often widely accepted by the student's peer group or by his parents, often block further investigation into the causes of phenomena. Personification, the attributing of human aims and objectives to the behaviour of non-human objects and superhuman deities, also direct

the students' attention away from the search for a better answer. Confusing the cause with the effect and vic vice versa is another common mistake. Students must learn to questionwhether or notthe event caused a second, even though the two seem related by time and by location. They must learn to question well accepted ideas when evidence indicates that they are of questionable validity.

4. Skill in testing hypotheses. Rigid following of instructions whether given by the teacher or outlined in a laboratory manual, does not teach students how to test hypotheses. Practical laboratory experiences should be more than simply exercises for the pupil to do. In order to learn scientific processes, students must be allowed to devise their own methods of testing hypotheses. The first criterionion of an experiment is that it have adequate controls that will allow the student to draw valid conclusions. Second, the experiment should include accurate measurement. Third, the investigation must be closely related to the problem being studied. And finally, the sample of material being worked with must be representative of the whole.

D. Synthesis of data

1. Ability to synthesize data into generalizations. This is the well-known objective of inductive reasoning. The student who is to become a productive user of the scientific processes must eventually be able to unite various data into an original unique generalization. Out of several observations, he must construct a single theory that will explain all of these and predict accurately the results of other observations. In the view of the teacher, the process that the student uses for this synthesis may be logical one. Or it may appear to be "creative" or intuitive. Whichever process is used, the end product is a statement which is original so far as the individual student is concerned.

2. Willingness to withhold judgement until sufficient information is available. Any scientifically minded person should be willing to suspend judgement until all the information necessary for the formulation of a valid conclusion has been collected. Hasty judgements cause the blocking of an individual's thought processes.

Judgements are based on the ability to organize data into meaningful wholes, as well as on conceptual

understandings. Incomplete data encourage the careful student to look for additional information. Ambiguous or inconsistent data should have the same effect.

(a) It makes the student take stock of the available information.

(b) It involves the interpretation of data along various dimensions.

(c) It implies the identification of inconsistencies in the data.

(d) It involves recognition of hasty generalizations.

(e) It involves examination of the extent to which logical reasoning led to generalizations.

E. Evaluation of data

1. Ability to evaluate evidence. One of the most complex of the skills that make up the processes of science is the evaluation of evidence that has been collected through experimentation. Once a bit of datum has been identified, its value must be assessed. Two criteria are generally used in this evaluation.

(a) Reliability, which refers to the trustworthiness of the data in question: Were the variables of the experiment properly controled? Were the measuring instruments appropriate for the measurements being taken? Were the instruments read accurately? Are the data stable, or will they change when the experiment is repeated?

(b) Validity, which has to do with the degree to which an experiment actually measures what it was intended to measure: Does logic support the manner in which the experiment was conducted ? Were the proper data collected ?

2. Skill in evaluating arguments. Many conclusions in science are probably based on insufficient evidence. This will be especially true in the case of conclusions made by immature students. These conclusions must be evaluated solely in terms of the logic of the arguments offered to support them. The science student must be able to consider conflicting arguments and evaluate each of them in terms of both its internal consistency and its external logic. He should be able to do this without allowing his personal preferences or desires to prejudice his evaluation.

3. Ability to distinguish among assumptions, hypotheses, theories, and established principles. These terms are used here to indicate four types of conclusions, each at a different level of reliability. An assimption is the lowest level, being based entirely upon crude logic and casual observation leading to taking it for granted that something is true. A hypothesis

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has a great deal more likelihood of being correct, since it is based upon both logic and the evidence of a practical situation. A conclusion becomes a theory after a great deal of experimental evidence has indicated that it is probably true. And a principle becomes established after it has been evaluated by experts in the field and has been found to be accurate at all times and in all places. Lastly, the distinction among these four levels is not often clear cut. Even the most experienced scientists will generally disagree on the classification of a certain idea. However, the student must learn to make such distinctions for himself, always recognizing that he may have to reevaluate his ideas as more evidence is presented.

Process and product in science teaching

A seeping change in science teaching

A great and significant ferment has penetmated the field of science teaching. It is impossible to say when and where this evolution began; no doubt it has stemmed from several different sources. The trend was clearly identifiable in the nineteen twenties and thirties. The began to accelerate just after World War II, and is now surging ahead with unceasing vigour - a full-fledged science education phenomenon in its own right. By now this new movement has been responsible for literally dozens of new science courses, from primary classes through the university curriculum. New teaching films and equipment have come into being, new styles of laboratories, new kinds of examinations. UNESCO and UNICEF continue to contribute talent and funds to this movement, and the Governments of many nations have assigned fiscal support as well. This powerful movement in science education has many names, yet it has none. Terms such as "concept development", "heuristic", "inductive", 'process approach," and "inquiry" have been used to describe this "new science" and the "new mathematics" to which it is intimately related. No scientific or educational institution is

exclusively identified with this movement, and no professional association espouses the trend as its very own. The phenomenon belongs to no one, yet it belongs to everyone.

This new movement has several schools of thought. Not all its proponents agree with each other on u underlying educational theory and its applications. Yet it is clear that most persons active in the field are pushing in the same direction.

A new look at the nature of science

If there is one thing which characterizes the "new science", it is a new look at the fundamental nature of science. This new view has been generated from a variety of sources. Classroom teachers and educational theorists have helped to be sure, but much of the pioneer thought has come from working scientists, philosophers of science, and distinguished scholars from other disciplines.

The older viewpoint held that science is a collection of knowledge, an area of subject matter, an array of facts and formulae and names and symbols: content. The new movement does not deny this view of science, but it holds this is only a part of science. Another aspect- at least as important

should be considered too. This other aspect of the scientific enterprise includes: the methods scientists use to gain new knowledge and the attitudes involved in their behaviour. The scientific enterprise also includes the activities of scientists, and the role of science in a society. One might say that the older view of science was concerned with what scientists know : now this has been supplemented-- not replaced-- with what scientists do. These two interdependent aspects of the scientific enterprise are described in many terms: " subject and method," "content and activities", "knowledge and behaviour". We shall use a well accepted pair of terms throughout these pages- product and process. Because most readers are abundantly familiar with the product of science, we shall begin our discussion with the process of science.

The scientific enterprise as process and product

By the term process of science, we mean the things that science and scientists do. We mean the way they locate information in books and magazines, the way they learn through observation, the way they experiment (that is, manipulate the

environment for purposes of special observation), the way they develop hypotheses, the way they test these hypotheses, the way they communicate their ideas to others. This is sort of things we refer to as scientific methods. We think that not only scientists, but all men and women and boys and girls can become more successful and more satisfied individuals if they have competence along these lines. By process of science, we also mean the patterns of thinking which we sometimes call scientific attitudes. We mean curiosity, honest doubt, tolerance for the opinions of others, openmindedness, willingness to admit when one is wrong, and an inclination to make decisions on the basis of evidence rather than tradition, superstition, or emotion. Here too we think that people— scientists and others— are better off if they behave according to these patterns.

By process of science, we also mean the role of the scientific enterprise in a modern nation. We mean the part to be played by science in improving India's agriculture and health and industry and communication and transportation. We mean the

part to be played by science in improving India's agriculture and health and industry and communication and transportation. We mean the function of science in improving general standards of living and in helping establish personal and national security. Perhaps, most of all, we mean the thing that science and scientists do above all -- they seek satisfying explanations for observed phenomena. Seen thus, science is a specialised kind of curiosity, a highly intellectual enterprise in which each and all can participate, each at his own level of competence and sophistication. What then is meant by product of science ? This is the other side of the coin. This is the side which is basically knowledge, including facts and figures, formulae and equations, principles and scientific laws. This is, indeed, the side of science to which most teaching effort in most countries has usually been directed. We do not mean to imply that product of science has no place in modern education, that it should be replaced by process of science. We do mean however, that two kinds of changes are in order.

For one thing, we are no longer content to spend all our educational efforts teaching product of science. Instead, we wish to give process of science a comparable share of our attention and interest. And even to the extent--and it is a large extent-- that product of science is still a teaching-learning objective, the emphasis is changed. We are less interested in memorisation of large numbers of specific facts than we are in useful understanding of a limited numbers of principles and basic ideas. We are less interested in superficially covering the full length and breadth of science, and more interested in achieving comprehension in depth of representative fields of science. We are less interested in learning knowledge for its own shake sake and more interested in learning the uses of knowledge, and sources of knowledge. It is no longer sufficient to teach students what scientists know-- we need also to have students see how scientists have come to know it. Only in this way we can produce a generation of citizens who accept and appreciate the role of science in their lives and in the development of their country. Only thus can we educate a generation which includes a substantial minority of genuinely productive scientists, engineers, agriculturalists, medical doctors, and technicians. In a way, what is known

is not of ultimate importance---- this is recorded in the literature of the world. It is what not known that counts. We must produce a generation of scientists who can explore the unknown, and who can put the known to good use in new situations. And we must produce a generation of non-scientists who understand and recognize the role which science has to play in their own ---- and their nation's future.

Science product as conceptual themes

The new look at the product of science has important implications for the teaching of science. We do not cast aside the teaching of knowledge, but we change the emphasis. We strive not so much for sheer quantity as for quality, we seek not so much rote memorization as functional understanding. We aim not so much at the specifics of subject matter but at the broad understandings and basic ideas which they comprise. These broad understandings are coming into sharper and sharper focus in science education circles throughout the world. They go by a number of terms. The term to be used here is conceptual theme. Thus, we try to teach the product of science against the perspective of the conceptual themes which constitute the real structure of scientific knowledge.

What are the conceptual themes of science? Many scholars have proposed many lists. The exact nature of a given list is not so important as is the idea of thinking of knowledge in terms of some set of themes. A good set of conceptual themes should be reasonable in number, should have wide scope and application, and should have intellectual significanc Typically, a good conceptual theme cuts across familiar subject-matter boundary lines of science. A conceptual theme is not a substitute for knowledge— rather it is an understanding toward which specific knowledge contributes, and without which specific knowledge is relatively meaningless, useless, and uninteresting. Conceptual themes are closely akin to what Bruner describes as the structure of science in "The Process of Education".

Many scientists and science educators have tried to produce useful arrangements of conceptual themes. Two are summarized here by way of illustration which have been suggested by Brandwein in Teaching of Science and in Curriculum Development in Secondary Schools. Briefly presented, these are:

First classification

1. Under ordinary conditions, matter can be changed but not annihilated or created.

2. Under ordinary conditions, energy can be changed or exchanged but not annihilated.

3. There is an interchange of materials and energy between living things and their environment.

4. The organism is a product of its heredity and environment.

5. The universe, and its component bodies, are constantly changing.

6. Living things have changed over the years.

Second classification

1. Every effect has its cause or causes.

2. Scales for time, position, size and motion in space are relative, not absolute.

3. Natural laws are universal, demonstrable through time and space.

4. Dissimilarity and diversity are normal qualities in natural phenomena.

5. In spite of natural diversity, there are patterns of similarity among things in the universe; they are amenable to useful man-made system of classification.

6. Change is a normal condition in the dynamic continuity of nature.

7. In spite of natural change, the influence of heredity tends to maintain characteristics of living things from one generation to the next.

8. Interdependence and interaction with environment are universal relationships in nature.

9. Matter is particulate in nature

10. Energy interchanges accompany every natural occurrence.

11. Energy can be transmitted in a variety of forms and manners.

12. Fields of influence extend beyond the place of their origin.

13. Equilibrium is a condition towards which all system in the universe tend to evolve.

14. Living organisms are highly specialized systems of matter and energy.

15. The sum total of matter and energy in any isolated system remains constant.

Both of these sample sets of conceptual themes and many others which have been developed, are useful. It is less important which of the many proposed sets of conceptual themes be incorporated into a given science teaching program; it is more important that the program personnel accept the basic philosophy of science content being structured around some useful set of major generalizations, broad understandings, basic ideas, conceptual themes.

Balance between process and product in science teaching

What should be the relationship between process of science and product of science insofar as science instruction is concerned ? Fortunately, these two aspects of our subject need not compete with each other for time and attention. On the contrary, process and product support each other; each is supported and strengthened by its counterpart.

If we strive to teach scientific thinking to students, it immediately becomes apparent that we cannot do so without involving scientific principles. One cannot be taught how to think without having some knowledge with which to think. Children learn to make and interpret observations by actually making and interpretting them with real data in real situations, and this involves subject matter. Students cannot learn of the significance of science in their lives without also learning of the accomplishments of science. They cannot appreciate the work of scientists without knowing what they have done. Teaching toward the process of science cannot succeed without substantial support from knowledge, the product of science.

If, on the other hand, we strive to increase student's command of scientific knowledge, we find that much more than mere memorization of facts and

figures is involved. Students often succeed in commiting specific parcels of scientific information to memory without really understanding them or their significance. They sometimes learn blindly what scientists know without ever becoming acquainted with the process by which scientists know it. They become consumers of scientific achievements, never interpreters or appliers or producers of new ideas. They know well what is already known, but are unable to add more to man's store of knowledge. Product of science thus taught becomes a mere rhetoric of information, painstakingly memorized, seldom used, often disliked, all-too-soon forgotten. If, on the other hand, students are permitted to share in gathering the evidence on which scientific principles are based, they get a glimpse of the process by which the principles were developed. If they themselves participate in the development of representative principles, their understanding and their retention of the ideas is greatly enhanced. If from time to time, they can be a part of the creative process through which scientific principles grow, they taste the excitement of discovery and achievement-- such involvement can do much to give them a positive orientation toward science.

Thus we see that process and product— the two aspects of the scientific enterprise—not only support each other in the laboratories of scientists, but also in the classrooms of boys and girls. Experience has shown that once teachers get the idea of this "new kind of science teaching", they like it. Students get the idea sooner, and they like it too. The "new kind of science teaching" turns out to be more stimulating, more effective, and more useful for students and teachers alike— and for all of them, more fun.

TEACHING SCIENCE THROUGH DISCOVERY

Posing the problem

In the most of the classrooms, science is being taught and learned as a body of facts which are infallible, unalterable and once studied shall serve life-long to the individual. If we continue with these cliches, we are sure to continue with rote memorization of mere facts and minutiae of science on the part of the learner. In that case, science teacher shall continue to function as a disseminator of information. This is evident even in those classrooms where teachers are graduates and postgraduates in science. The situation is worse at the primary stage where even teachers are unqualified in science subjects as well as there is absence of equipment and other facilities for science teaching.aMtehearning. where there is a favourable environment for science teaching and learning, the brute fact of the matter still remains. Science teacher is neither a purveyor of scientific information nor he is an initiator

of learning for learnings sake. On the other hand, he is a stage setter and children are initiated from "learning to thinking". This will help in preparing critical thinkers, ready to meet the challenges of unknown, unpredictable future. This is the purpose of science teaching where we relate present with future in classrooms and children acquire many abilities to function as a problem solver "par excellence"; a rare quality of a working scientist as well as a highly distinguishing characteristic of any first class educational system anywehre in the world.

The changing concept of science

A valid and functional concept of science and the use of the proper methods of teaching science will make science teaching and learning effective and useful. When we talk of science, merely, as a body of hard facts, we miss a significant part of it. We call it processes of science or the modes and methods of discovering the

knowledge or facts of science. Joseph J. Schwab thinks that science should not be taken only as a "rhetoric of conclusions" but it should also include the "exhibition of the course of inquiry". Study of science should help in uncovering the laws of nature. After all, science is the "interpretation of nature' and man is its 'interpretor' Science has assumed a dynamic outlook. The findings of science are tentative or provisional. They are subject to correction in the light of new evidences. Scientific knowldge is revisionary in character with a "temporary codex". Even doctorines of long standing were altered by new findings by new evidence The history of science is studded with many glaring examples to substantiate it. Hurd has very aptly presented an emerging concept of science.

Facts in and themselves simply do not make a science. A science is not simply an abstraction from empirical data, but an intellectual creation often suggested by the data. It is the discovery of

order among the data that makes the science..... Science is an intellectual activity which arises from personal experience and takes place in the minds of men. It is simply a way of using human intelligence to achieve a better understanding of nature and nature's laws .

To initiate intellectual activity in classrooms, we need emphasis on the processes of science or modes of discovering scientific knowledge. This changing concept of science demands a change in our teaching, in our institutions, and in ourselves who are working as science teachers. While a child is passing rhough the process, he acquires the concepts of science, gathers information of conceptual schemes and ultimately develops a picture regarding the structure of science. Therefore, it is essential that we understand the proper and deeper meaning of science inherited in its nature, and practice discovery learning to find the structure of science.

What is discovery ?

The prominent workers in the field of science education advocate the use of discovery method of inquiry approach in science teaching. Many strongly favour the use of problem solving method. Webser's American Distionary interprets discovery as: to discover means to know; to find out; to uncover it, etc; and discovery means, anything discovered. Similarly, to inquire means, to seek information and inquiry means an investigation or examination etc. Other workers describe disvoery or inquiry as an attitude; a state of mind; a way of learning; a process of investigation; an uncovering, and a search for truth. There seems to be subtle difference between discovery approach and inquiry method. On problem solving, of course, David P. Ausubel contends that it involves discovery learning, if problem solving is meaningful and worthwhile. The aforesaid meanings of discovery/inquiry appear to be skindeep and peripheral. A critical analysis of few definitions along with some examples will clarify it further.

On enquiry Schwab states, "to teach science as enquiry means, first, to show students how knowledge arises from the interpretation of data. It means, second, to show to students that the interpretation of data indeed, even the search for data- proceeds on the basis of concepts and assumptions that change as our knowledge grows. It means, third, to show students that because these principles and concepts change, knowledge changes too" (2).

Gagne states that enquiry is apparently a set of activities characterized by a problem-solving approach in which each newly encountered phenomenon becomes a challenge for thinking (3).

Bruner, here, adds: I do not restrict discovery to the act of finding something that before was unknown to mankind, but rather include all forms of obtaining knowledge for oneself by the use of One's mind ....permitting the student to put things together for himself, to be his own discoverer(4).

Two Illustrations

Activity 1: Classification of objects: Students of primary classes were given a few seeds of different colour, shape, and size. The students were asked to classify them into different groups. Children observed things critically and tried to find out differences in physical properties. Many times, children changed an object in order to observe further minutely, sometimes used instruments or aids to find out details. They repeated observations to improve reliability. Thus, on the basis of observation, they perceived similarities and differences in these objects; separating them in different groups, developing in the process arbitrary classification scheme etc. While trying to recognize them, children were using the processes of science and simultaneously gaining scientific knowledge or concepts of science. At higher grade level, students may classify animals and plants and may use their own criteria of classifying things.

Activity 2 : Interdependence of plants and animals.

A study of an aquarium will help in understanding the relationship of aquatic plants with fishes. Children learn about the living conditions of plants and animals. They try to find out the significance of water, temperature acidity, and alkalinity for living. Here, students use observational skills, classificational abilities, abilities of conducting experimentation and drawing inferences from recorded data. To acquire these concepts, students use different modes of inquiry.

From above, it is easy to see that discovery learning is characterized by the following pupil and teaching behaviours:

1. Children participate actively in the process of learning for they are exposed to the fundamental scientific phenomena.
2. Children try to learn themselves and, in due course of time, they become self learners.
3. Children try to organise and systematize their findings which provide an opportunity for analytical thinking.

4. The role of the teacher is minimized. But he is not out from the teaching learning process. He functions more as a 'manager' or 'organizer' of learning activities, rather than a disseminator of information. In fact, he is a participant not only in his own education but also in their self education.

Is discovery approach new ?

The recent resurgence of interest in the laboratory work or experimentation show that discovery approach is recent in origin. But it is not so. The above mentioned characteristics of discovery approach show that many of these were in use since long. Today, they have gained currency because it has been included in all curricular programmes of science. A brief historial perspective is given here to peep into the various processes involved therein. Socrates claimed that he never taught his students. He raised questions and tried to present situations where students can find answers to their questions. Of course, it needs

thinking on the part of the learner. Socratic method is one of the glaring examples which present a few elements of discovery approach. In the present century of the child, the Progressive Education movement gave many significant strands of discovery approach. Examples are: project method, activity method, problem solving and child centred learning. All these new educational notions centre on the active involvement of the child in the process of learning. Discovery is also associated to a considerabl degree with the inductive method, scientific method and Armstrong's heuristic method. John Dewey in 'How We Think', highlighted many aspects of discovery approach in general and creative critical and reflective thinking in particular. In the post-sputnik era, Schwab, Bruner, Gagne, Suchman and Ausubel are the world known proponents of discovery approach. The advocated discovery learning in science teaching. They also subscribe to the new slogan that

education should help in preparing "critical thinkers". In our country, Dr. A.C. Joshi gave such a clarion call.[1]

Why discovery approach in science teaching ?

There are many advantages to the learner when he applies discovery approach in learning science. Bruner contends that use of discovery results in added intellectual potency, shift from extrinsic to intrinsic rewards; learning the heuristics of discovery; and the aid of memory process. Why ? Because teaching science through discovery shows science in flesh, blood and bones. Here, we can emphasize processes of science, a very valuable and a significant aspect of science. Children try to find out concepts of science when they learn science through discovery. They also learn that science is more than mere facts given in books or mentioned by the authorities because it was known to them. Learning concepts of science,

conceptual schemes in science give an idea of the structure of science. Novak contends that the structure of science may be viewed as the 'system of major generalizations or concepts together with the process by which these concepts are obtained and enlarged'. Children will understand concepts as they see them in the context in which they emerge and grow. Discovery based science programme take into consideration the natural characteristics (willingness to investigate, the ability to imagine procedures of doing work etc.) of children. Willingness to investigat the ability to imagine procedures of doing work and to obtain an acceptable solution.

Role of the science teacher in discovery learning

The science teacher has to play a key role in discovery learning. He has to create an intellectual climate in the classroom. He carefully plans a sequence of learning activities covering a period of time. Planning involves preparation of instructional

material suited to the particular age group. The teacher is not only an 'initiator' of discovery teaching but he has to sustain the intellectual climate in the classroom until learners realize the significance of self learning. The science teacher also helps students in selecting proper activities, in identifying proper topics and providing guidance.

Conclusion

There is enough scope for teaching science through discovery if we understand it properly and put sincere efforts. It has its own values in learning. But discovery approach is not a panacea of all ills in science teaching. In the fifties, almost all science curricular projects started using it. It can be used through laboratory work, by experimentation, demonstration or discussion. It does not demand sophisticated instruments as is generally supposed. There are a few observations

which we should always keep in view:

1. Discovery approach is not applicable in all situations.

2. A thorough study of different schools of thought in discovery learning is needed on the part of the teacher. It includes ideas of John Dewey, Jean Piaget, Joseph J. Schwab, Jerome S. Bruner and Robert M. Gagne.

3. Psychological and sociological aspects of discovery learning need thorough understanding.

4. Activities organised for learning through discovery should be graded so as to suit the age level of children.

5. Discovery approach may be practised right from grade one onwards by using exploratory, inventive and discovery lessons as attempted in the SCIS project.

Improving Classroom Instruction in Science Through Evaluation
(Problems and Perspectives)

Introduction

Evaluation movement is about twenty years old in our country. In this period, there is hardly any individual of significance in the secondary education who has remained uninfluenced by the massive invasion of this movement. This is a splendid achievement. Being a late starter, Rajasthan is doubly proud because it also happens to be the top state in the implementation of new ferments in evaluation on a very large scale in so short a period under the enlightened leadership of the State Education Department and the Board of Secondary Education. The question that naturally arises in anybody's mind is: What has been the impact of evaluation on the improvement of classroom instruction in the face of the known concept and functions of evaluation? One hardly finds the answer. There are several reasons for the same. First, in excitement, the basic ideas were borrowed from foreign literature

without doing any serious homework in the country. Secondly, at the evaluative stage of the lesson, too much specificity was injected so that the consequent reasoning of the advocates of evaluation became transductive, that is, prelogical, from particular to particular, at the cost of generality of concepts. Thirdly, the explosion of knowledge range the death knell of objectification of answers, that is, statistical reasoning became dominant increasingly. Fourthly, no attempt was made to relate evalution with the methodology of instruction. The direct relationship between the two was automatically assumed. Fifthly, there was no philosophy of evaluation to guide the movement; formulation and reformulation of objectives more and more productively, productive teaching methods and imaginative evaluative strategies leading to replanning, reteaching and retesting. Evaluation meant recognition, completion, true false, multiple choice and matching type test items. Sixthly, in the name of easiness as well as the vastness of task, attitudes and

appreciations remained a foreign territory to the influence of the evaluation movement. It thus turned out to be a case of miseducation rather than inadequacy of instruction and testing on a large scale. Sevently, our University Professors showed little interest in this movement. Lastly, whereas the evaluation tended to enhance objectivity, the internal assessment hindered it colouring everything in the process. Even copying became respectable in the eyes of the pupils. It is, therefore, least surprising that evaluation as visualized in its early years of development did not cross the hump of the camel (5).

Some basic considerations

(a) Objectives. They are our educational intentions which give direction to our efforts provided we take them seriously. Let us attempt to see them in terms of kinds of changes which we wish to bring about as a result of our schooling process, not an easy task because more could mean

worse. Let us examine our attempts, to state behaviours in regard to a particular school subject which our various categories of students should show. 'Are they capable of acquiring these behaviours? is again a question of judgement as well as of imaginative procedures. Another disturbing question, "What will be the students doing with the content, we give to them in our day-to-day instruction?" We find ourselves in several difficulties: intellectual and emotive for our educational system, despite our efforts to change it essentially remains clerical in spirit at its very heart. The consequences of our failure to tackle this porblem are obvious. Teachers have lost interest in the formulation of objectives for they believe that they can arrive at the destination in an unspecified bus driven by somebody else. Narrowly speaking, they simply care to cover the syllabus with a heavy heart rather than oncover it. They do not care to hold in focus these terms which are more specifiable, meaningful,

and in terms more measurable than vague words like understand, familiarize, know and acquaint etc. Imagine the change in the classroom interactions and consequent pleasure both to the teachers and their pupils when at the end of the lesson, they carry out different processes of thought on the same concept. Consider the following sample terms:

1. Analysing
2. Applying
3. Assembling
4. Checking
5. Collecting
6. Classifying
7. Discovering
8. Defining
9. Dismantling
10. Degeneralizing
11. Hypothesizing
12. Limiting
13. Locating
14. Mathematizing
15. Outlining
16. Quantifying
17. Reformulating
18. Selecting
19. Summarizing
20. Telling
21. Tranferring
22. Validating
23. Verifying
24. Writing

It is possible to use each of the above mentioned key words in many diverse situations in the formulation of behavioural objectives in different types of lessons.

For example, selecting could mean, selecting could mean, selecting a fact, concept, principle, approach, process, tool or even non-selection (rejection). By planning lessons behaviourally, the teacher, to a large extent, decentralizes the teaching-learning process but does not lose the centralized control of the class.

(b) Learning experience-- methods and outcomes. In the Handbook of Research on Teaching, N.L. Gage says, 'Teaching is an intriguing, important, and complex process. Because it is intriguing, it attracts scientific attention. Because it is important, it merits careful research. Because it is confusing, research on teaching needs many sided preparation'(1). Several problems of learning theories and educational technologies lie hidden here which evaluation movement in this country did not at all try to bring to the surface. Nobody really knows how Indian children form scientific and mathematical concepts or appro-

diverse problematic situations. We also know very little how the various method work with different categories of children: oral methods, observational methods and practical methods. This does not at all exhaust the various available methods: documentation, debating, audio-visual methods, individual and group methods and coordinativ methods (field of interest method). We also forget that a student who is consulting a dictionary, map, supplementary material and interviewing important people from all walks of life(of course relevant to the problem under study) is documenting himself. He is thus face to face in a true-to-life situation and is, in his own way, at his own level, trying hard to assemble documentary material which he studies and collates in order to show the interdependent limits. In short, overall objective of all these above mentioned methods is to develop reflective atmosphere in the classroom and the laboratory. It is painful to report that in a survey report on Physics Teaching in Rajasthan

we found that the physics teachers hardly use any variety in teaching, for example, teaching in a wider setting, discovery approaches, use of problem solving procedures and teaching through individual and small groups projects. To put in other words, approach to teaching remains the same despite the drastic changes in curriculum, philosophy and materials. Cramming and copying then tend to short circuit everything educational(2).

Psychological rooting

It is pity that verynlittle is known in this country about the psychological structure of any one school subject. On close analysis, it must be pointed out straight away that the elements of unit and lesson plan or even the so-called principles of teaching do not at all clarify and psychological principles. Apart from reinforcement, we have to learn a lot in science teaching from the Gestalt

and Piagetian Psychology. The former visualizes an active role for the learner in his day-to-day learning. It discourages the acquisition of facts, concepts and principles without understanding. It stresses divergent thinking, that is, going far beyong the starting point in one's thinking by setting up all sort of hypotheses (open ones) and testing them against the given data and the demands of the problem. Thus the consequent scientific concepts or insights are gained through a series of small acts of discovery.

At the higher secondary stage, the educational implications of the Geneva School are immense. Piaget appears to say somewhat as follows:

Intelligence develops in stages, that is, prelogical (0-7years) and formal (11-16). During the first stage, the child's thinking is governed by the perceptual considerations of the situation.

At the higher stage, it is tied to the concrete situation that is, reality rather than possibility

dominates realistic thinking. He can
dominates his thinking. At the third stage, possibility dominates realistic thinking. He can then see the problem from several angles at the same moment.
He then further says that a teacher can't give an idea to his students until and unless they try hard to develop their own cognitive structures. Otherwise, it amounts to lecturing a pig. Carl Rogers also makes more of less the same point that a teacher can't influence his students straight away. The consequentes of teaching are either insignificant or harmful at its worst. Learning, in order to be worthwhile, should be self discovered and self appropriated.

Piaget emphasizes Education for Understanding. The Job of the teacher is then clear. His job is not merely to impart factual information to his pupils but to discover the relevant and necessary operations implicit in a given unit of teaching. He should present the learning situations in such a way so as to make them invent and discover knowledge, as far as

possible, on their own steam. He further adds that we do not give children this type of experience when we teach them either too fast or too much. 'Teaching means creating situations when structures can be discovered, it does not mean transmitting structures which may be assimilated at nothing other than verbal level'. It is for this reason that John Halt did not find any substantial difference between dull and bright children studying in very expensive schools of America; the former forget before the examination; and the latter after the examination(6)

Illustration

No instructional planning of the conventional variety is required. Expose your pupils, whatever their age range, to the following questions. Help them examine their various answers, both right and wrong. Arrange their responses in the ascending order on the blackboard, the last response being the

correct answer to the problem. Always ask for evidence or the type of experiment necessary to answer the question.

1. A bell jar is placed over three candles of different heights which are simultaneously lighted. Which of the candle will extinguish first ? Give reasons.

2. If you go swimming at the baths, you may have noticed that the swimming pool looks less deep that it actually is. This is called its 'apparent depth'. Ram one day measured the real depths and the apparent depths of a number of swimming pools. He collected his results as follows:

	Real depth	Apparent depth
1.	8 ft	6 ft
2.	12 ft	9 ft
3.	20 ft	15 ft
4.	28 ft	21 ft
5.	100 ft	75 ft
6.	80 ft	?
7.	?	120 ft
8.	x ft	?
9.	?	y ft

Write a statement which tells how you found the various answers. This statement may also help you to answer the third question written below.

3. A flesh tank is 52 inches deep. It is filled with water and a fish is slipped into it. A boy looks down on the fish from the above surface and the firsh appears to swim 24 inches below it. His friend put his head under the tank and at the same time, the fish appears to him 12 inches away above the bottom. The problem is to find the thickness of the fish, you can ignore the thickness of the glass. Assume that real depth/apparent depth= 4/3. Majority of the students fail to solve this problem.

Therefore, phrase the same question in the following form:

a) Draw a diagram.
b) What is the apparent depth of the fish when seen from above?
c) What is the real depth of the fish?
d) What is the real depth of the fish seen from above below?
e) What is the real depth of the fish when seen from below?
f) What is the combined real depth of the fish when seen from above as well as from below ?

g) What is the real depth of the tank?

h) Now determine the thickness of the fish.

The order of the questions mentioned above could be different. Our only purpose is that the students should tackle parts of the problem unaided. The questions in the form mentioned above do not supply the answers. Instead, their answers have to be thought out(6).

4. Write short answers to the following questions:

a) What will happen if we continue to live in a dark and unventilated room; what is the scientific evidence for your answers ?

b) Prevention is better than cure. Discuss

c) Balanced diet is essential to human health. How can a poor person manage to eat a balanced diet on the cheap in our country?

Attempt to conclude your answer with special reference to substitute foods.

5. Investigative type.

a) What is the effect of the magnetic field on the growth of baby mice? What control experiments will you set up to test your various hypotheses ?

(b) To study the immersion of cylindrical can varying the depth of orifice from the free surface of liquid (water) and keeping the area of cross-section same throughout.

6. Inviting formal and informal questions at the end of the lesson:

(a) Why is soil of Rajasthan sandy ?

(b) Do animals think ?

(c) Can't river flow upwards ?

(d) Why can't we get milk back from curd ?

(e) What experiments did Galelio perform which made him world famous ?

(f) Under what circumstances was Ohm's law discoverd?

Let students react to any of the above mentioned questions. One obtains quite a large number of varied answers. These are obtained the way the children see the question. The teacher's job is to help them see the basic essentials of the problem as well as to separate them from its nonessential aspects. Students commit all sorts of errors, for example, arbitrary errors, that is, when their mastery on the problem is very weak.

Consider their arbitnary errors on the third question:

(a) This problem can't be solved until and unless a real fish is in front of you.

(b) Why not use a rubber and be simple enough ?

(c) In my opinion, it all depends upon where the fish is.
Apparent and real depths can change. This question is quite impossible to solve.

(d) My answer is 40 inches because 40+12=52.

(e) There is essentially no difference between real and apparent depths. After all, the fish is where it is. It can go anywhere.

(f) When the fish is at the bottom, it is easier to calculate but when it is midway, it is difficult. It may slip, it swims you know (6).

These responses need to be educated out before the children really begin to structure the solution of this problem. It is in this context that Bruner talked of 'more than one dimension of accessibility, more then one level of accomplishment, more than one aspect of mobility, and more than a simple degree

of organising concept'. In passing, it may be mentioned that there is another approach as well. Let students solve the problem on their own at home or in the library. Let them be free to seek outside help. Let them sign a contract somewhat as follows:

I have read the assingment carefully and the way it is to be evaluated. For getting the minimum grade D, I have to answer all the starred questions. In order to receive a higher grade, I have to attempt the various remaining questions as instructed.

The grade I wish to contract for-----

Signature

This approach goes a long way in developing self-confidence and persistence among senior students(3).

Concluding statement

It is a mistaken notion that there is a direct relationship between classroom instruction and evaluation. If analysed differently, evaluation does provide a lot of feedback necessary for setting all right the various misconceptions

of students. For example, error analysis and corresponding reteach lessons. Right throughout the school, the student's thinking has to pass through the following stages, majority of the student reaching the thrid and fourth stage:

1. Do as you are told (repeat, recite, obey)
2. See and understand as you work(classify, pbserve, identify).
3. See the situation from a distance(compare, contrast, discriminate, describe, illustrate)
4. Master the problem at a distance. Separate Yourself from the situation(explain, justify hypothesize, infer).
5. Create and discover knowledge and skills. This stage has strong links with self education, a matter of pride for any educational system anywhere in the world.

Like teaching, electricity, learning or intelligence, studying evaluation is also a ghost like activity. An imaginative attempt is necessary to make it as transparent as possible so that it becomes

intellectually and emotively acceptable. We educate our young boys and girls in a piece-meal frame of reference, that is, we fail to educate them in a wider setting: no centre of learning or project experiment, because that necessitates evaluation under different conditions with new testing instruments which may be semi-objective. Advances in evaluation will take place only when deep seated assumptions are questioned and exploded. Only then we enhance the low teaching as well as testing abilities of our teachers and examiners. To quote Lorenzo Linesenbee:

An ideal test is a well constructed test devised by the teacher himself, aimed at the goals and content the teacher has established. He along knows what he has covered and what directions were taken during the course. By devising his own tests, he does not teach for the test, but he uses tests to determine how well he accomplished the objectives, set for himself and for his students' (4)

Lastly, the growing literature on evaluation needs to be understood and assimilated with care.

Otherwise, we will be pulled down by its very weight. It will be then our fault, if we act mechanically and unreflectively in our day-to-day work: 'They work to pass, and not to know'. But the spirit of science takes it own revenge. 'They do pass, and they do not know', said T.H. Huxley while commenting on the study habits of the undergraduates of his day.

The Piagetian Questionnaire for The Secondary School Going Pupils

How do you think ? (Questionnaire)

I am interested how people think when solving daily problems. You already know from daily experience that everybody thinks differently. You are going to be asked to think about some interesting problems in science. You will find that each problem can be solved in two, three, or four different ways. You are allowed to think in as many different ways as you can. In order to make your thinking easier for me to understand, you have been given some idea of how you are to tell me what your solution would be -- either by completing diagrams, filling in statements, making some statements and suggesting some quite different method etc. For this, sufficient space is provided and you can have more paper if you ask for it. This information about your thinking is very valuable to me and you should report almost all of it. It does not matter even if it looks silly. It is just possible that your approach may turn out to be the right one. This you can do --

(1) First read the problem as a whole. It will tell you what you are supposed to do.

(2) As you go through the problem, many ideas will strike you. Please write down your ideas in the spaces provided. It is very likely that I may have missed some of your ways of thinking. For any different ones, you should use the spare space provided. Do not forget to number your ideas.

.....2

(2) If you find that the problem is difficult then do not get disheartened but do solve any part of the problem you can. I am sure you can do this.

(4) Please be neat, clear, and precise in your writing. You are free to reduce the amount of writing on any problem by summarizing a lot of attempts in any way you like.

Still further, every child was asked to give his personal post-test reactions on each of the problems by answering a series of ten different questions which were:

1. Did you find this problem difficult?
2. Did this problem interest you ?
3. Have you done a problem of this type before ?
4. Did you try all possible methods to solve this problem?
5. Did you solve a part of the problem ?
6. Where were you muddled by this problem ?
7. How did you feel when you were solving the problem?
8. What other ideas did you try in the problem that did not work?
9. Do you want to put any question on this problem that may help you in its solution ?
10. Any other reaction that you want to report.

.....3.

In the second part of the study, individual approach was employed, where each subject was observed solving a series of nine different problems over a period of over two hours, either a whole morning or a whole afternoon. Instead of the post-test reactions, we took the immediate (pre-test) reacions to the problems on presentation by putting the followng six questions:-

1. Do you understand this problem ?
2. Do you find this problem difficult?
3. Do you think you can solve this problem ?
4. Have you done a problem of this type before ?
5. Do you find any difficult words in this problem ?

66. Do you find this problem understandable ?

The meanings of difficult words, if asked, were explained. Problems were presented one by one and in the same order to every pupil. On certain questions, hints and cues were given. These were repeated for those who asked for repetition. Every effort was made that these hints and cues did not suggest answers to the problem even indirectly. Hints and cues on the other hand simply helped them to start on the problem. Every pupil was asked 'to talk aloud' as he or she progressed along or worked on the various problems. In practice, this technique turned out to be quite difficult, because it interfered with their thinking. Consequently, a compromise was sought by asking every pupil

.....4

to explain his or her step. This process (processes) leading to a particcular step in the problem was recorded on the problem sheets. At the end of the session, every pupil was given a second opportunity to reattempt any part of the unslved problems. We were thus able to obtain their maximum performance on each of the problems under study.

1. Ram is taller than Shyam by 2 cms.

Ram is taller than Mohan by 6 cms.

Ram is shorter than Sohan by 6 cms.

If Ram's height is 200 cm, then answer the following questions.

A. What is the height of Ram ?

B. What is the height of Mohan ?

C. What is the height of Sohan ?

D. What is the height of Shyam ?

E. How much is Mohan shorter than Shyam ?

2. Fill in the blanks to understand the relations of the given series.

- 5 ____ - 10
-10 ____ - 15
-15 ____ - 20
-20 ____ - 25
-? ____ - ?
-35 ____ - ?
-x ____ - ?
? ____ - y

10x1 = 10
10x2 = 20
10x3 = 30
10x4 = 40
10x? = 50
10x? = 70
Continuous
10x? = 100
10x? = x
10x? = y

3. There is a spring balance with you. It has no markings on it. One day your mother asked you to get 15 grams of sugar. She wanted to test your ingenuity. For solving this problem, she gave you several beakers, each weighing 5 gms. Moreover, she also gave a scale, a pencil, thread and 3 weights of 1 gm, 2 gms, and 3 gms. You can tell me what else you need. That will be given. You have to weigh 15 gms of sugar in one attempt only. How will you solve this problem for your mother.

Before you begin solving this problem, please answer the following questions:

A. Have you done a problem of this type ? Yes/No.

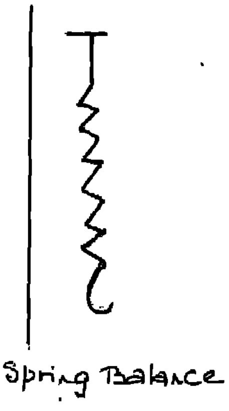
B. Do you understand this problem ? Yes/A bit/No

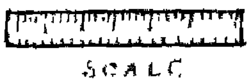
C. Do you find this problem difficult ? Yes/A bit/No.

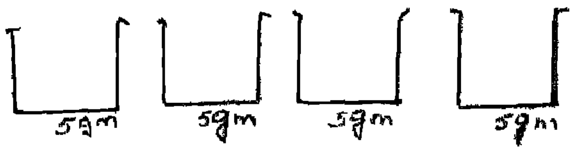
D. Can you solve this problem ? Yes/A bit/No.

E. Do you find any difficult word in this problem ? Yes/No.

If yes write down that word.







4. We have three rectangular glass cubes, each measuring 3 cm in length, 2 cm in width and 1 cm in thickness. They were put one by one in a large measuring jar. Before immersing them the level of water in the jar stood at 40 cm. Now answer the following questions:

A. What was the level of water before immesing the three rectangular cubes ?

B. What is the length of the rectangular cube ?

C. What is the width of the rectangular cube ?

D. What is the thickness of the rectangular cube ?

E. What is the volume of the rectangular cube?

It is given to you that a rectangular cube/block of 1 cm lengh, 1 cm width and 1 cm thickness raises the level of water in the cylinder by 1 c.c. ?

F. What will be the level of water in the cylinder on immers^ing all the 3 rectangular cubes ?

(Hint: Actual cubes can be shown)

5. There is a rectangle which is 25 cm long and 15 cm wide. A man goes four times around it at the rate of 4 cms per second. Now answer the following questions:

A. Draw a diagram and show the distances on it ?

.....7

B. What is the total distance covered when the man goes once round the rectangle?

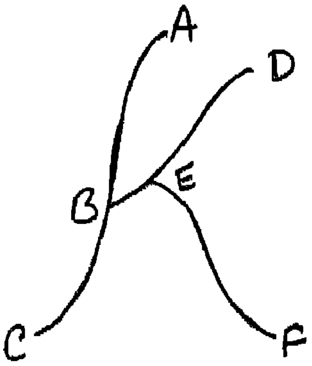
C. How much time does he take in covering a distance of 4 cms?

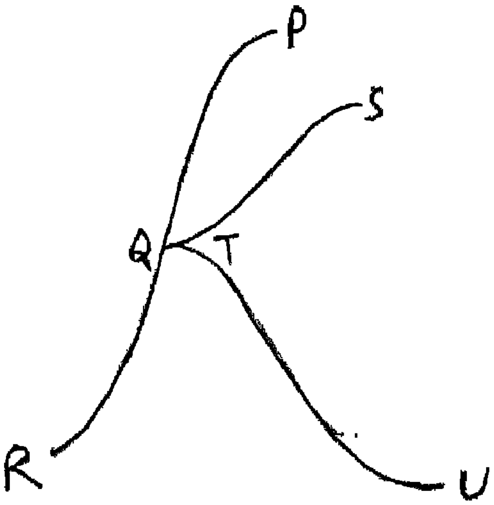
D. How much time does he take for going once around the rectangle ?

E. Suppose he rests for a second at the end of each round, how much time does he take for completing just 4 rounds ?

(Hint: Help the pupil in drawing the diagram. Let him also mention the distances)

6. A letter 'K' is given in two different sizes - one small and the other large. It is given that the lengths of the arms of the small letter and the large letter are in the ratio of 2:3. On the basis of this information, answer the questions.





A. If length of the arm BE is 4 cms, what will be the length of the arm QT ?

B. If the length of the arm EF is 8 cms, what will be the length of the arm TU ?

C. If the length of the arm AB is 16 cms, what will be the length of the arm PQ ?

D. If the length of the arm BC is 10 cms, what will be the length of the arm QR ?

E. If the length of the arm DE is 9 cms, what will be the length of the arm ST ?

(Hint: Those pupils who are not able to solve the problem, ask each of them to determine the ratio of the various arms of the letter 'K' (enlarged and small). The problem may be then handled experimentally, later on)

7. Ten persons from a village went to a hotel for an evening meal. They ate 4 chapatis per head at the rate of 10 paise per chapati; 10 plates of vegetables at the rate of 50 paise per plate; one cup of ice cream each costing a rupee per cup. After meals each one of them drank a cup of coffee costing 50 paise each. At the end of their meals, they gave two ten rupees notes to the manager of the hotel. Now answer the following questions:

A. How much in all did they spend on chapatis ?

____

B. How much in all did they spend on vegetable plates?

____

C. How much in all did they spend on ice-creams ?

____

D. How much in all did they spend on coffee ?

____

E. How much did they spend per head ?

____

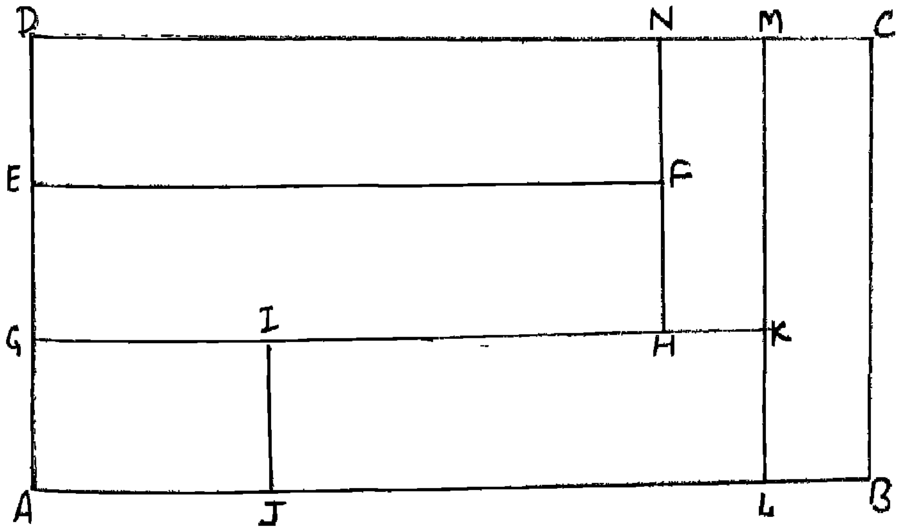
F. How much did they spend in all ?

____

G. How much additional money was demanded by the hotel manager ?

____

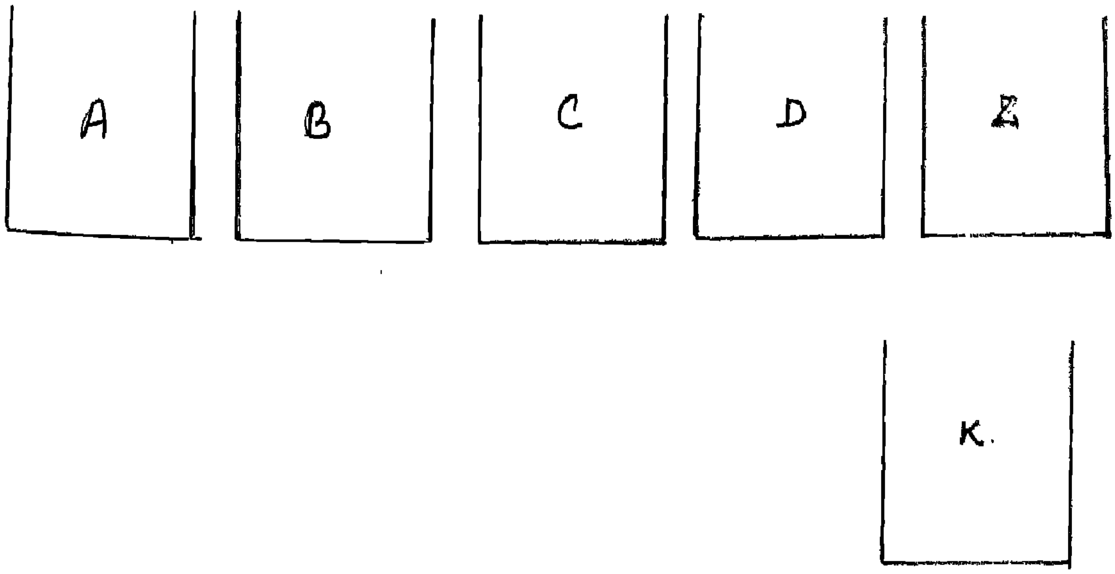
8. Have a look at the diagram given below, count the maximum number of rectangles that you can make?



(Hint: ABCD is a rectangle)

......10

9. There are 4 beakers on the table. They are labelled A, B, C & D as shown in the diagram below. A small distance away there is another beaker Z. Ram did an experiment. he took parts of contents from beaker A, B, C, D and put them in another empty beaker K. After this, he took some liquid from beaker Z and put it in the beaker K. An interesting thing happened. The entire liquid in the beaker K turned yellow. After some time his friend Mohan came and enquired Ram about the formation of yellow colour. While answering this question Ram forgot how he had done. Now Ram carried out several experiments to obtain yellow colour in beaker Z but failed. Your problem is to write down all the possible methods by which yellow colour may be obtained in beaker Z. Please remember that you are to write down all the possible methods. Before you begin solving this problem, please answer the following questions:



.....11.

A. Have you done a problem of this type before ? Yes/No.

B. Do you understand this problem ? Yes/A bit/No.

C. Do you find this problem difficult ? Yes/A bit/No.

D. Can you solve this problem ? Yes/A bit/No.

E. Do you find any difficult word in this problem? Yes/No.

for example -

Ram took some liquid from beaker 'A' and put it in beaker 'K'. Then he took some liquid from beaker 'Z' and put it in beaker 'K'. He did not get the yellow colour.

Now write down all possible combinations he must use to get the yellow colour. You can write the first method as shown below.

(1) AZK	(2)	(3)
(4)	(5)	(6)
(7)	(8)	(9)
(10)	(11)	(12)

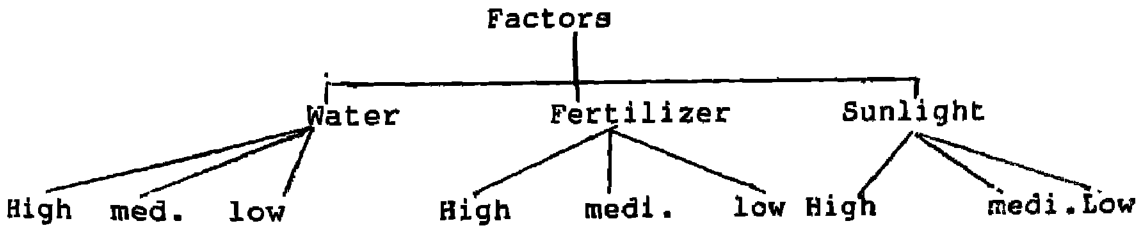
Hint: If the student fails to understand the problem, ask him to make as many combinations as possible by usng 3 digits such as 6, 7, 8, or 6, 8, 9 and 4 digits 6, 7, 8 and 9.

....12

10. A farmer had some magic seeds. He did not know how to grow them into healthy plants. The only thing he know was that their growth depended upon the following factors:

1. Water
2. Fertilizer
3. Sunlight

His problem was to know the right amount of each of the three factors mentioned above, to be present to make the seeds grow into healthy plants. So, he considered giving the above factors at three levels (amounts) was follows:



He then bought several earthen pots with soil in them and sowed a seed in each of them and designed several experiments to find solution to his problem. Consider his first experiments.

He sowed a seed in the first pot. He put a lot (high amount) of fertilizer in it. he also gave plenty (high amount) of water and kept the pot in direct (High) sunlight.

Your job is to plan as many experiments as you

.....13

can possibly think of. Please see that no factor or percent of the factor is missed by you.

In the table given below, the first experiment is done (entered) for you. Now continue to write the other possible experiments.

Pot No.	Exp. No.	Water	Fertilizer	Sunlight
1.	1	High	High	High
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Please continue

11. There is given a board having nine squares upon it. The top three squares (A,B,C) were painted blue, the middle three squares (D,E,F) were painted white and the bottom three squares (G,H,I) were painted red. When they were painted the second time it so happened that the left three squares (A,D,G) got painted red, the middle three squares (B,E,H) got painted blue and right three squares (C,F,I) got painted while. Thus the different colours got mixed up and changed jin the various squares as follows:

1. The square which was painted blue and red or vice-versa looked grey in colour.

2. The square which was painted blue and while or vice-versa looked light blue in colour

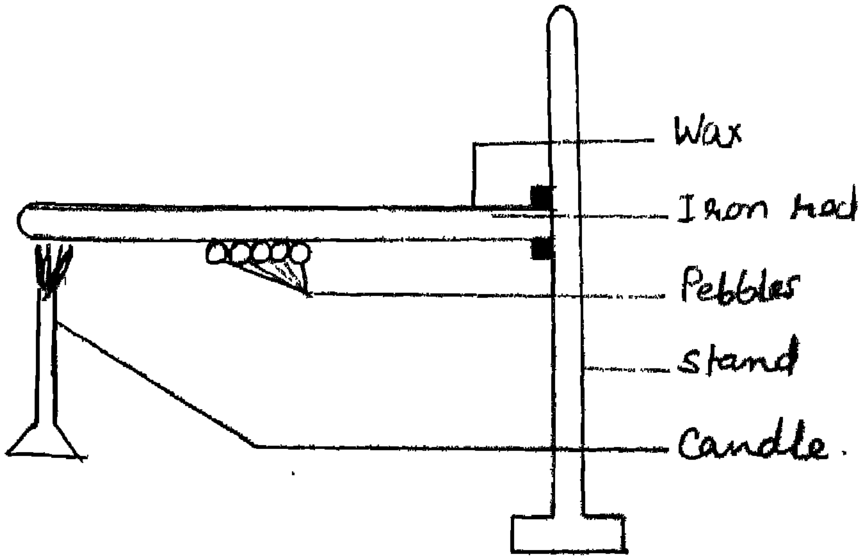
3. The square which was painted red and white or vice-versa looked pink in colour.

You please write down the name of the colour in each square of which it looked like after the two paints:

A	B	C
D	E	F
G	H	I

1. Colour of square A.
2. Colour of square B.
3. Colour of square C.
4. Colour of square D.
5. Colour of square E.
6. Colour of square F.
7. Colour of square G.
8. Colour of square H.
9. Colour of square I.

12. I am showing you an experiment. I have also drawn the diagram for you. Please have a close look at the diagram. You see some pebbles fixed to the iron rod with the help of wax. Now, if we heat the rod at the point 'A' what is likely to happen ? Surely, the pebbles are bound to fall on melting of wax. Your problem is to state as many factors as possible which make the pebbles fall. You are free to change the experiment set up as you like.



factors:

(1)

(2)

(3)

(4)

(5)

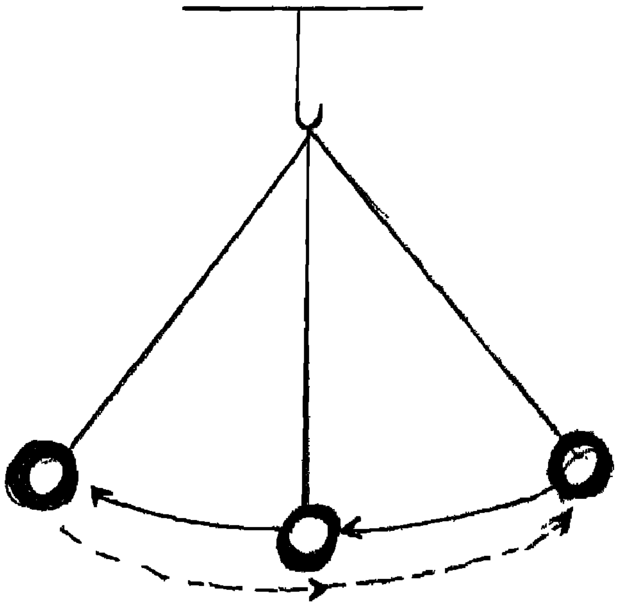
13. A simple pendulum is shown in the figure below. The bob of the pendulum oscillates on both sides of the centre. The movement of the bob from thed centre to the left end back of the centre, then to the right end and back to the centre is called an oscillation. Time taken in one oscillation depends upon:

(i) length of the string

(ii) Volume of bob

(iii) weight of bob

Suggest experiments which isolate these factors.



Experiment No.1

Experiment No.2

Experiment No. 3

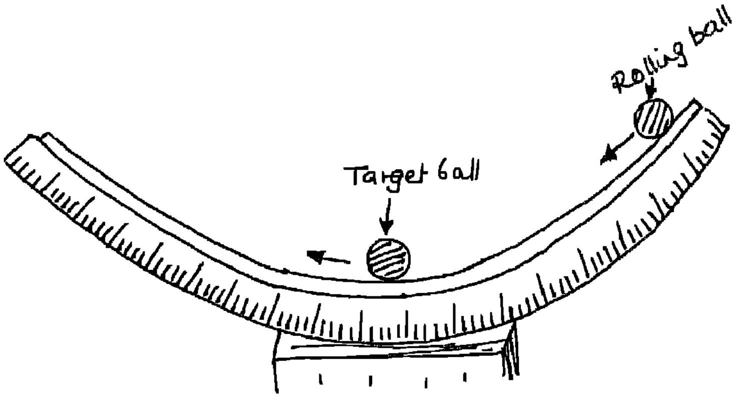
Experiment No. 4

Experiment No. 5

Hint: Show them three ball having same volume but different weights. Also show three balls having different volumes but same weights.

......18

14.



The Ramp.

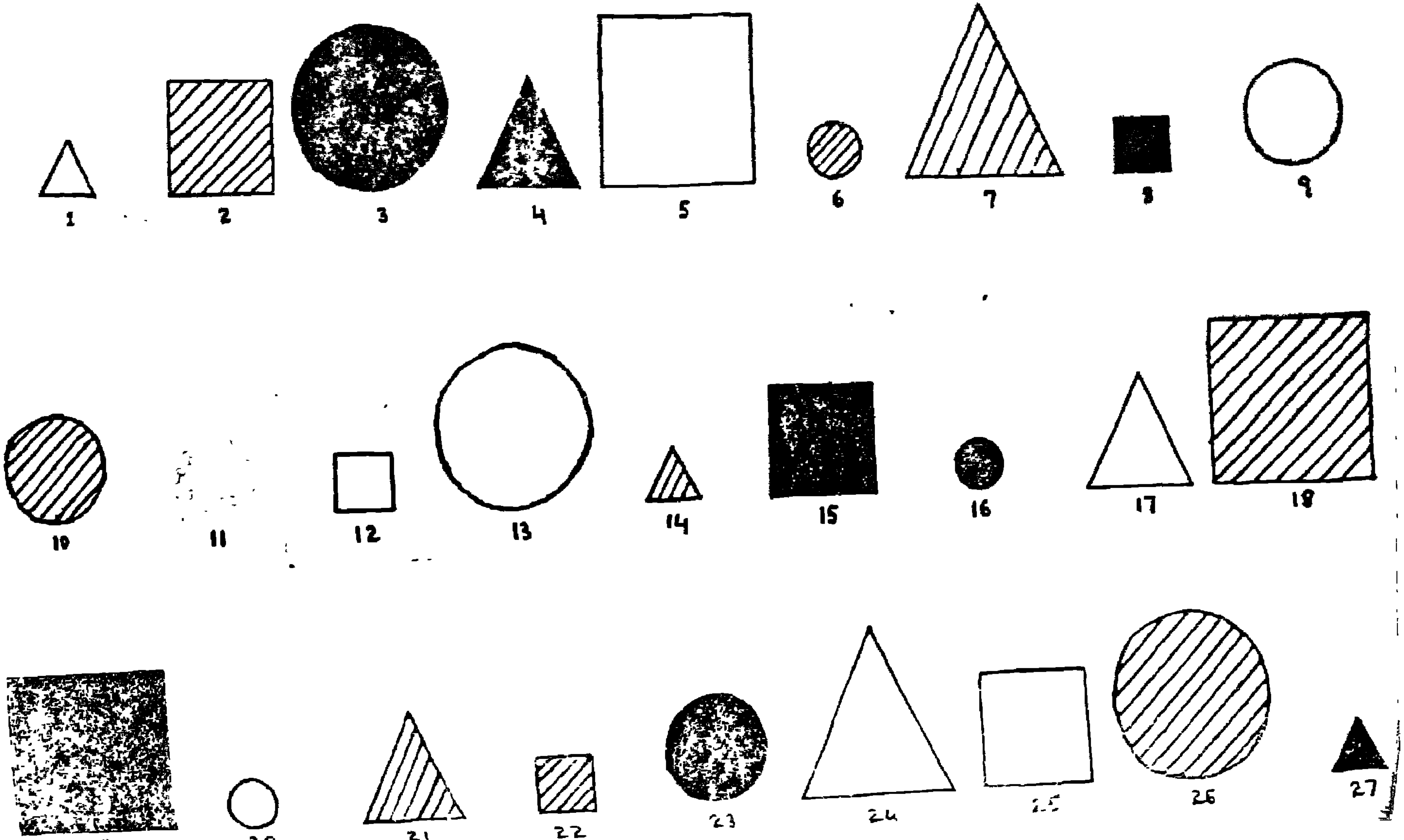
The moving of the target sphere depends on the following factors:

1. The weight of the target sphere.
2. The nature of the surface of the groove.

Suggest experiments to test the above factors.

1. The weight of the target sphere.
2. The nature of the surface of the groove.

15. A gardner gave a bunch of flowers of different types to his son and asked him to classify the flowers into different groups. The boy put the roses in one group, chammeli in the other and so on. Then the gardner asked him to further classify the roses into different categories. The boy put the red roses in one category and while roses in the other and so on. Now you go through the task given ahead and try to perform as demanded.



चित्र सं० 3

There are given some geometrical figures on the previous page. Each figure has been assigned a number for its identification. Classify these figures into three main categories in such a way that similar figures come under one category. You are to write only the numbers of the figures under the category I, II and III to which they belongs.

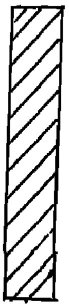
Category I	category II	Category III

.....22

Now further sub-classify each category into three sub-categories in such a way that similar figures of each category come under the three sub-categories of the same.

category I			category II			category III		
Sub category			Sub category			Subcategory		
A	B	C	A	B	C	A	B	C

16. Three rods of equal length and shape are given to you. One of them is of sugar, second is of iron and third is of wood. After painting all the three rods look similar.



A

B

C

Now your problem is how can you identify them. List down all possible ways you can think of.

1.

2.

3.

4.

17. There is a rectangular fish tank made up of thin glass. It is 52 cm deep. It is full of water and a fish is swimming in it. A boy looks down and the fish appears from the above surface and the fish appears to swim 24 cm below it. It is its apparent depth. His friend put his head under the tank at the same time and the fish appeared him to swim 12 cm away from the bottom. It is also its apparent depth. It is also given that the ratio between the real depth and apparent depth is 4:3. To put it in other words, it means that if the fish is really 4 cm away from the bottom it will appear 4 cm away from the bottom it will appear to be only 3 cm away from top or bottom. Your problem is to find the thickness of the fish. You can ignore the thickness of the glass in your calculations. Before you begin solving the problem, answer the following questions.

...24

A. Have you done a problem of this type before ?

Yes/No

B. Do you understand this problem ?

Yes/a bit/No

C. Do you find this problem difficult ?

Yes/a bit/No.

D. Can you solve this problem ?

Yes/No

E. Do you find any difficult word in this problem ?

Yes/No

First Method

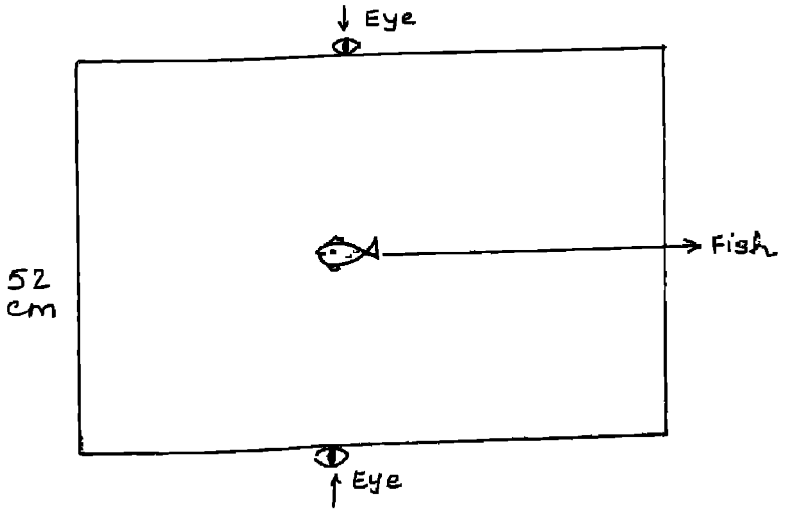
1. After reading draw a diagram
2. What is the real depth of the tank?
3. What is the apparent depth of the fish as seen from the top ?
4. What is the real depth of the fish when seen from the top ?
5. What is the apparent depth of the fish when seen from the bottom ?
6. What is the real depth of the fish when seen from the bottom ?
7. What is the combined real depth of the fish when seen from above as well as from below ?
8. What is the real depth of the tank ?
9. What is the thickness of the fish now ?

....25

Second Method

1. What is the real depth of the tank ?
2. What is the apparent depth of the tank ?
3. What is the apparent depth of the fish when seen from above ?
4. What is the apparent depth of the fish when seen from below ?
5. What is the combined apparent depth(s) of the fish when seen from above as well as below ?
6. What is the apparent depth of the tank ?
7. What is the apparent thickness of the fish ?
8. What is the real thickness of the fish ?
9. State your method of attack.

Hint: Draw a diagram so that pupil could start thinking.



For those who attempt this problem successfully ask each of them what data was required for determining the length of the fish. Again draw a diagram.

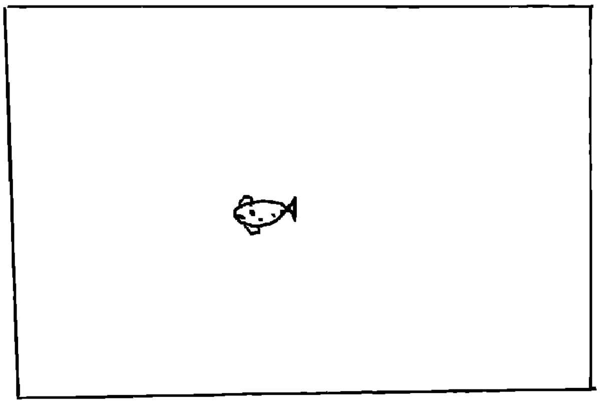


fig 14

18. The photograph below illustrates cases when certain sets of cards are picked and then shown. Four of such shows are recorded in a table, arranged at the side of the photograph. The chances in each show for picking cards marked with Jockers in both right hand and left hand set are found, by adding the number of these cards marked with Jockers in the cards shown. You are to write the answer or say the quotient in the blank spaces provided in the table.

....27

Table showing details of the sets of cards shown in game in Jocker cards

S.No.	The show	Position of the sets	No. of cards marked with Jockers	No of cards unmarked	Total No. of cards shown	Chances of picking cards marked with Jocker
a.	First show	Right hand	4	1	11	
		Left hand	4	2	9	
b.	Second show	Right hand	4	1	9	
		Left hand	3	1	9	
c.	Third show	Right hand	2	1	9	
		Left hand	4	2	9	
d.	Fourth show	Right hand	2	1	10	
		Left hand	5	2	10	

Questions:

A. Arising from the calculations in the table, the chances of picking cards with Jocker in:

(a) The first Showis ______

(b) The second show is ______

(c) The third show is ______

(d) The fourth show is ______

B. Is it in (a) or (b) or (c) or (d) that the chance is the greatest ?

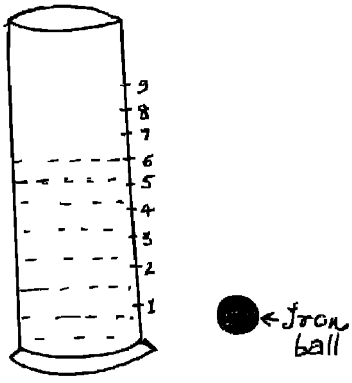
C. What is the numerical value of this greatest chance found in question No. 2?

D. Arrange the chances of picking cards marked with Jockers (obtained in Q. No. (1) in increasing or decreasing order.

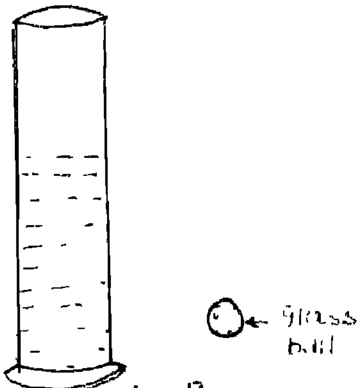
E. State a rule by which you can tell where chances of picking cards marked with Jockers, lie ?

19. Two cylinders A and B of equal size and volume are on a table. Both are filled with water at a similar level.

....30

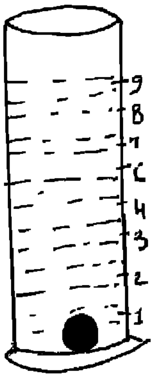


cylinder A

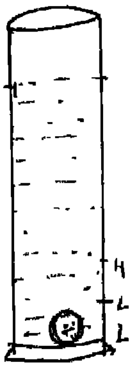


cylinder B

What have two balls of Iron and glass. Iron ball is heavier than glass but same in size and volume as glass ball. Both sink in water. When we keep the iron ball in cylinder A, the change in water level is shown in the figure. If we keep glass ball in cylinder 'B' then tell -



A



B

A. The water level in cylinder 'B' will be more/less/remain same.

......31.

B. What will be the water level in cylinder 'B' ?

C. Explain your answer -

20. Read the questions below and answer them carefully?

A. A blind man can see upto a distance of 100 ft with one eye. How far can he see with two eyes ?

____

B. It takes two minutes for a handkerchief to dry up in the sun How much time will it take for 20 handkerchiefs to dry up when placed in the sun at the same time?

____

C. There are eight birds sitting on a tree. A Hunter came thereby and shot dead two of them. How many birds are now left on the tree?

D. It takes 10 minutes for a boy to reach his school. How much time it take for ten boys if they start for the school at the same time ?

____

E. A man crosses a stream in a boat in 10 minutes. How much time will it take for five men to cross the same stream in the same both ?

____

F. Ram has four friends. They are Shyam, Mohan and Jahaj. Find the name of fourth friend.

____

G. A st^ick is of 10 cm length. It is cut by a cm/minute. In how much time will it be cut into 1 cm pieces?

____

H. A boy was inside a dark room. There was a heap of red and yellow socks inside it. How many minimum number of socks should he pick up with a view to get a pair of the same colour ?

____

I. Suppose a donkey has two horns. How many horns in all do eight donkeys have ?

____

J. Suppose there are some ducks swimming in a single line under a bridge. Two are in front, 2 in middle and 2 at the rear. How many ducks are there in all ?

....33

K. A cow is standing besides a tree. A cord of 50 cm. is tied around her neck. Tell how far can she go for eating the grass ?

____

L. Suppose you are the driver of a bus. You have 50 passengers in it. At one place 15 passengers board the bus and 15 get down from the bus. At the other place again 5 board the bus and 5 get down from it. Please tell__

(A) How many passengers in all are there in the bus ?

____

(B) What is the name of the driver ?

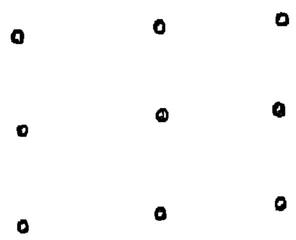
____

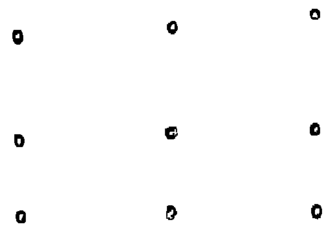
M. A handkerchief has four corners. Shyam cut one of them by scissor. How many corners are left now ?

____

21. I have marked down 9 dots below. Have a careful look at them. Draw four lines in any manner you like in such a way that these lines touch all the dots at least once. In case you find that you have drawn more than four lines, then attempt again. You can try as many times as you like.

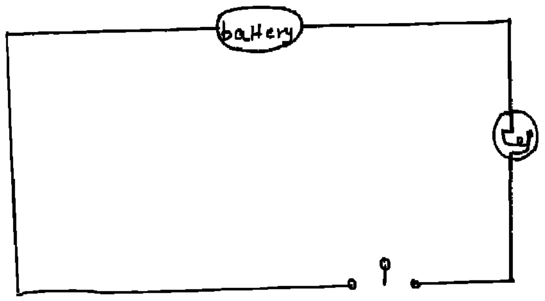
....34



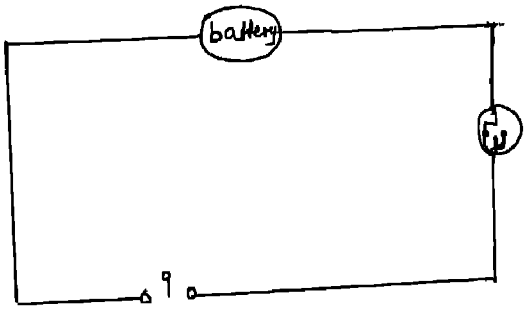


22. We have planned an electric circuit (An alternative problem) in which the children were expected to discover not only the arrangement of switches but also their type (one way or two way switch) by switching on or off lights. The following instructions for this type of problem on a working sheet turned out to be quite difficult. Consequently, this problem was simplified to a great extent by asking the pupil to develop a parallel circuit from the first two simple circuits on the working sheet. Moreover, the two simple circuits were drawn on the black board and one-way add two-way keys were circulated for individual observation.

The above mentioned electric circuits were drawn a follows:

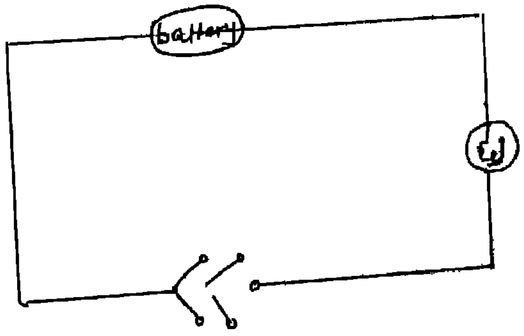


You can use this key anywhere. The key only makes (completes) or breaks the circuits.

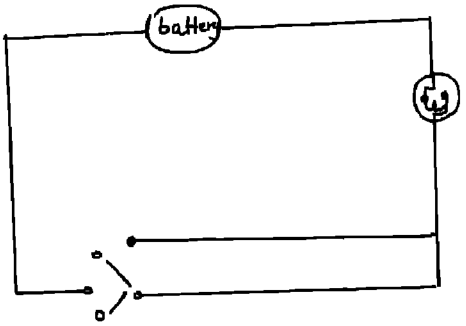


This is a two-way key because you can make or break the circuit or you can light on and light off the bulb in two different ways.

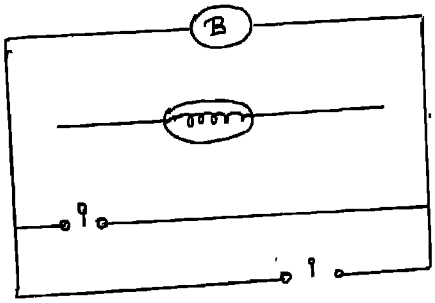
You are free to use the switch anywhere you like and in any position you like.

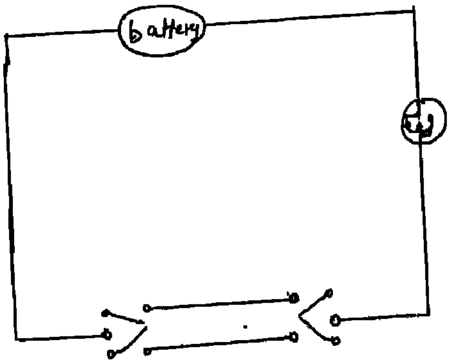


....36.



The aim was to evolve another circuit fulfilling the demands of the problem. These two required circuits to be developed are now shown below:



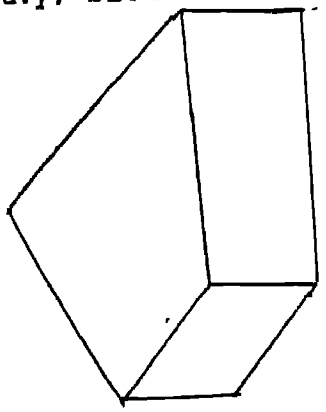


......37.

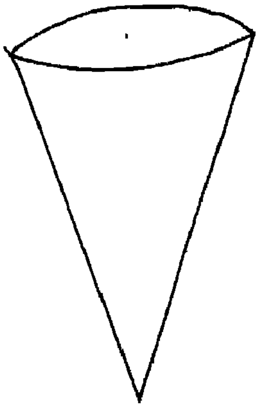
Our main interest was not in the specific solution of the problem but in its essential grasp. Consider now the problem and the way it was presented.

You are given a battery, one bulb, some one-way and two-way switches and some connecting wires. Your problem is to find a circuit enabling you to switch on and switch off from different places in a room. Complete as many of these diagrams as you find necessary to the needed circuit and when you finish, wrie down a statement telling me how it works.

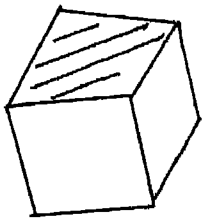
23. Study carefully the three blocks, A, B and C arranged as shown in the photograph below and then answer the question that follow. It is known that block C is heavy, block B is heavier while block A is heaviest.



A



B



B

......38.

Questions:-

A. Block C is lighter than block B ? Yes/No

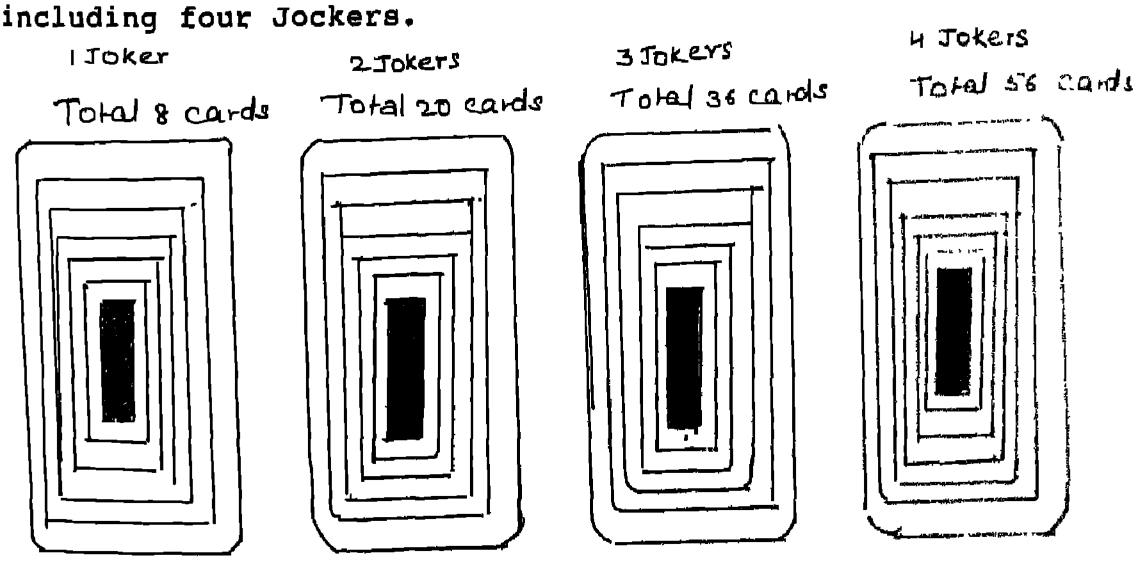
B. Block C is lighter than block A ? Yes/No.

C. Block A is heavier than block B and C put together ? Yes/No/depends.

D. Block can be arranged according to their weights, starting from light than lighter and finally the lightest ? Yes/No.

E. Using the letters: A, B and C which, respectively, represent the blocks, arrange an order say of heaviest, to heavy or lightest to light.

24. There are four groups of playing cards in the figure given below. In the first group there are 8 cards with a single Jocker. Second group has 20 cards includng 2 Jockers. Third group has 36 cards including three Jockers and remaining fourth group has 56 cards including four Jockers.



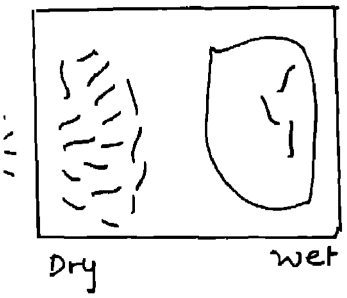
A. In which group there is more printing of picking Jocker cards ?

B. Explain your answer.

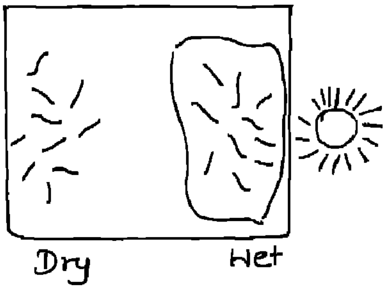
C. If we keep together groups one and four and groups second and third, then were is the chance of picking Jocker cards ?

25. A student was interested in finding out how insects responded to light and moisture. He took four boxes made up of glass. In the box he fixed up a bulb for lightening arrangemnt and kept a wet piece of paper for moisture. In the centre of each box he kept 10 insects. After one day the insects dispersed in the four boxes in different manners. See the following diagrams:-

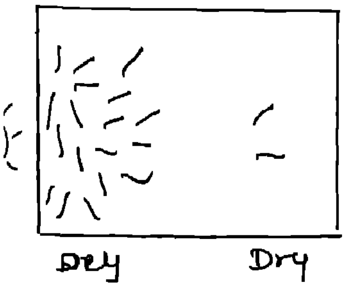
1.



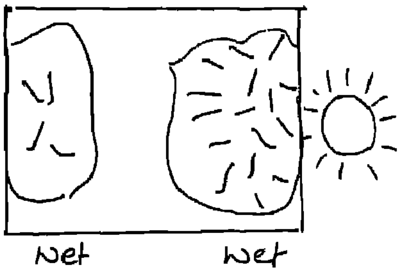
3.



2.



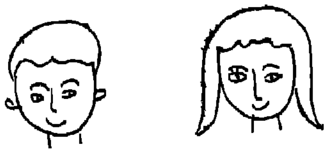
4.



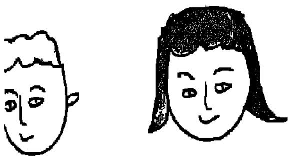
Answer the following questions:-

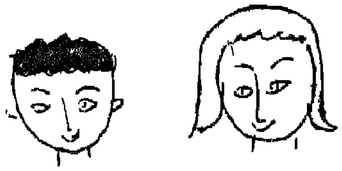
(1) What conclusions can you draw from box 1 and 3.

(2) What conclusions can you draw from box 2 and 4.



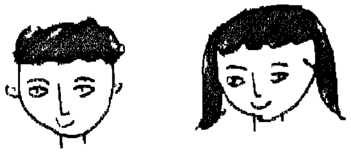
CARD'A'





CARD'C'

CARD'B'



CARD 'D'

.26. This is a game using cards like these (All single cards A, B, C and D are shown so that a child can see all possible hair colour combinations). It is quite easy but there are lots of instructions tomake sure you understand it. So listen carefully.

Each card shows a boy and a girl together. We are only interested in their hair colour. So I want you to look particularly at their hair colour. The boy may have red hair or yellow hair and the girl may have red hair or yellow hair.

I am going to show you different set of cards. Each time you should look at the boys and see which girl theychoose on the cards in front of them. You know that boys can have red or yellow hair and that their girls can have red or yellow hair. Remember it is just a game. Nothing to do with hair colour in real life.

Each time I show you some cards I shall ask you to look at them and tell me about the boys with yellow hair and boys with red hair, although sometimes you may only be able to see boys with one hair colour.

For each set of cards your task will be to tell me the general rule about boys choosing girls.

SCORING-SUMMARY OF GENERAL CRITERIA

Item No	cards Used	Logical Description	Response Category: Pre-operational	Response Category: Concrete Operational	Response Category: Formal Operational
i	AAA	$(p \cdot q)$	Teaching items		
ii	BBB	$(p \cdot \bar{q})$			
1	CCC	$(\bar{p} \cdot q)$	Failure to grasp simple relation between boys and girls' hair colour as depicted.	Able to see relation on cards, i.e. to describe how the hair colours depicted go together.	Able to predict about colour not shown on cards--simple'don't know' not adequate. Answer must include idea that either (i) boys' hair colour not depicted could go with either red or yellow or (ii) there is no evidence because there is no picture.
2	DDD	$(\bar{p} \cdot \bar{q})$			
3	AABB	$(p \cdot q)(p \cdot \bar{q})$	Purely descriptive response with no integration or irrelevant response.	Able to classify double relation shown and to integrate response, i.e. not to describe each card single.	Items 3, 8 As above Items 4, 7 Child must indicate that all boys of both hair colours only like girls with yellow (item 4) or red (item 7) hair. Items 5, 6 Child must make a definite statement about relationship, i.e. that boys like their girls to have same (item 5) or different (item 6)hair and that nothing else is possible.
4	AACC	$(p \cdot q)(\bar{p}\ q)$			
5	AADD	$(p \cdot q)(\bar{p} \cdot \bar{q})$			
6	BBCC	$(p \cdot \bar{q})(\bar{p} \cdot q)$			
7	BBDD	$(p \cdot \bar{q})(\bar{p} \cdot \bar{q})$			
8	CCDD	$(\bar{p} \cdot q)(\bar{p} \cdot \bar{q})$			

9	ABCD	$(p.q)(p.\bar{q})$ $(\bar{p}.q)(\bar{p}\bar{q})$	As above	General classificatory description	Rule of no rule i.e. any pairing possible.
10	ABCC	$(p.q)(p.\bar{q})$ $(\bar{p}.q)$	As above	As above	Response should indicate clearly awareness that one combination is missing either by overtly stating this or stressing that (e.g. item 10) red haired boys do **not** choose red haired girls, or that they only choose girls with yellow hair.
11	ABDD	$(p.q)(p.\bar{q})$ $(p.q)$			
12	AACD	$(p.q)(p\bar{q})$ $(\bar{p}\bar{q})$			
13	BBCD	$(p.\bar{q})(\bar{p}.q)$ $(\bar{p}.\bar{q})$			

GLOSSARY

1. Abstraction

It is used in contexts like - physical, formal reflecting and constructive. In a way, it is on the extreme side of the term: concrete. Here the presence of the very object is not essential. So it is a mental activity which is further subjected to the laws of logic. Physical abstraction leads to the development of objective knowledge, formal or reflective type of abstraction is necessary for the growth of intelligence.

2. Action

It has a variety of context, say, as vast as behaviour. It is a sort of functional exchange between the organism and the environment. All this presumes internal structure as well as structuring and restructuring of the environment.

3. Adaptation : Organization; and accommodation as well as assimilation.

There is constant interaction between the organism and its environment. It has two aspects: namely, organization and assimilation and accommodation. At any moment, i is a sort of balanced state of biological organization within its environmental context. So, during the adaptation process, the organism goes on taking equilibration from a lower level to a higher level. Whereas the general organization remains more or less the same, assimilation and accommodation work simultaneouslyand are difficult to separate. The two work in opposite directions. The organism encounters difficult or odd situations. So it learns to accommodate them. Accommodation, therefore, applies a general structure to a particular situation which is different every time. So accommodation always contains an element of novelty. Restrictedly speaking, it leads to the differentiation of a previous structure and, later on, to the emergence of a new structure.

Assimilation, on the other hand, leads to the incorporation of operative action. The data from the environment are taken not in a mechanical manner but as a function of the internal structure.

Knowledge is false in the absence of assimilation. So a child must learn to assimilate as well as to accommodate. In short, assimilation implies to conserve as well as to identify. it s a process of intergrating new percentual stimuli into behavioural pattern (or scheme).

4. **Advance organizers**

These have been defined by David Ausubvel as "superordinate introductory material at a higher level of obstraction, generality and inclusiveness than the learning passage itself. They facilitate learning and retention from oral, written and visual materials through ideeational scaffolding. They thus go a long way in matching the incoming information and the mental development of children. At the same time, they should not be expected to be equally effective under all instructional conditions and outcomes.

5. **Affectivity**

It is the aspect of behaviour which covers terms like interest, motivation, energy, dynamics, sentiments, feelings, attitude and even maturation. It is inseparably associated with structural aspects of knowing.

6. **Algorism** (algorithm)

It is a way of solving problems(method of calculating) according to fixed rules. Here a class of problems is tackled together.

7. **Animism**

A child believes that everything in nature is endowed with consciousness, life and even purpose.

8. Artificialism

It is a belief held by children that man directs human phenomena. Sepcifically speaking, it is men who crated the sun, the moon, rivers, mountains etc.

9, Behavioural learning.

It refers to our social relationships which may develop without any kind of thinking. Science is pure activity with a single goal. In behaviour learning, one has to learn about the situation as well as seek success or reward. It is understood that these two goals too complete. It also informs us about how to process while approaching, say, thinking tasks.

10. Centration and decentration

It is the tendency to focus only one aspect of the physical situation. It gives a deformed view of objectivity. Decentration just reverses the situation. Two equal sticks remain equal in whatever way they are placed: side by side and even at right angle to each other.

11. Classification

It is a process or operation for classifying groups on certain criteria, for example, colour, side and weight etc.

12. Clinical method (Methode clinique or method of critical exploration)

It is a semi-scientific method developed by Piaget for exploring child thought. It does need specialized training. Under certain conditions, it can be used as a teaching technique too for achieving conceputal change.

13. Closure

Given a set A and operation O. By closure properly, we mean that combination of anytwo or more elements of the set A belong to the same set A.

14. Cognition (Cognitive process and cognitive development competence)

It covers the activities of the mind such as thinking, knowing, remembering, perceiving, recognizing, generalizing, memorizing, abstracting and imagining. Cognitive development refers to age related changes in cognition which occur throughout life. Cognitive competence means not only being sensitive to such type of situations, but handling all such new situations effectively and innovatively.

15. **Combinatorial system**

It is a structured whole of all possibilities (combinations) of objects, digits (figures), ideas and propositions. The well known problem here is that of colourless chemical liquids.

16. Concept(categoric and infantile). also functions of:

It is the meaning of a term which is rarely understood or grasped gradually, say, in the jcase jof constructs. In a psychological sense, it can be talked of as the individual's internal structure (scheme). It is nothing but a scheme of action or operation. Infantile concepts lack synthesis. They are the product of juxtaposition. It jgives rise jto syncretism; a sort of subjective unity to the various elements jof the situation still in disarray.

The main functions of concepts are:

(i) They simplify, classify and interrelate various experiences, events and processes. They, thus, become objective in character and further our knowledge. Incidentally, they also save us from cognitive load.

(ii) They interconnect themselves and constitute a hierarchy.

(iii) They are predictable, verifiable and usable statements.

(iv) They are economical in the sense that they save us jfrom repeated learnings. If forgotten, they can be reactivated easily.

17. Concrete operations.

These appear during the third stage of intellecual development as propounded by Piaget. These apply only to real objects and physical siuations. Their chief distinguishing characteristic is that of reversibility.

18. Conflict (Conflict equilibration)

It is a situation where the individual is not in a position to decide clearly. So there is an imbalance in cognitive structure which cannot last long. Hence, further development takes place. It is the inherent property of the organism to seek equilibration or balance. And this process goes on, for it is in the nature of organism to master the external environment sooner or later.

19. Conservation

It is a very powerful concept in Piagetian thought. In fact, the whole of our rational knowledge is based on it. It is a sort of realization that theamount of object remains the same, regardless of its shape, length, direction and position. the conservation of weight, area, length and physical quantities (continuous and discrete). One of its chief distinguishing features is reversibilityin thought. Conservation is constructed rather than given.

20. Construction and reflection

It is the genetdic process which is both constructive and reflective. Both enricch each other. Construction gives us new combination. Constructivism goes on transcending the already constituted systems in an open manner.

21. Control of variables

It underlies controlled experimentation. Here, one studies the influence of one variable on an other variable by holding the remaining variables constant. The experiment of simple pendulum problem is a case in point.

22. Co-ordination

It is in a way, the functional adaptation. It is a sort of unifying form when more than few actions are involved. It implies an action on internal structure.

23. Co-relation

It tells us the extent of relationship or association between any two variables. There are many types of correlation coefficients, for example, product moment biserial and Spearman Brown.

24. Decalage (horizontal, vertical)

It is a term (or phenomenon) which means inability of the child to solve another problem of the same nature at the same level of mental development which he had solved earlier. The underlying scheme of thought or the mental structure in both ases is more or less the same. It is called the horizontal decalage. For example, all problems relating to the scheme of conservation, say, that of mass, at the same level of mental development can't be solved. Hee, varied achieveent at the same level of mental development on the conservation of mass across other situations is involved.

In the case of vertical decalage, there is a shift in the passage of one plane of activity to another. In the case of vertical decalage, it is not possible for the child to solve a problem, say, that of conservation of angular momentum or volume or weight when he has so far mastered conservation of mass.

25. Deduction

It arises out of construction(s) formed at the interior of achieved groupings or groups.

26. Displacement

It is a change of placement for the child in the first instance, say, that of order. It is also a change of position.

27. Egocentricity

It is self-centredness. It is not to be confused with selfishness. In simpler words it means to see things from one's own point of view only. It can be seen also as a disequilibrium between assimilation and accommodation.

28. Empiricism

It is a philosophical school of thought which believes that all knowledge comes to us through senses. It also means search for knowledge using experimental methods.

29. Epignesis

Its coinage is attributed to William Harvey, the well-known discoverer of circulation of blood. Basing his observations on a chick, Aristotle said that the vital external force directed the various stages of development (differentiation of growth). Egg is pictured as unfifferentiated and homogenous. Psychological development is assumed to be similar to biological epignesis. Its key features are: (1) it involves firm causal sequence, (ii)This causal sequence is characterized by differentiation, complexity and organization, (iii) There is step-wise growth and at each step there appears qualitative structure.

30. Epistemology (Genetic)

It is a branch of philosophy which deals with the nature of knowledge, scientific knowledge in particular. How successive states of knowledge develop is a problem which can be studied experimentally from the psychological point of view. Piaget thus interconnected fruitfully the fields of biology, psychology and epistemology. Genetic epistemology thus studies the mechanistic growth of knowledge.

31. **Epistemological V**

It is attributed to Professor D. Bob Gowin who invented this heuristic device for illustrating the interplay of key elements in laboratory work. It is graphically shown below:

Conceputal

Questions/
problems

Methodological

Philosophy
Theories
Principles &
conceputal systems

Concepts: regularities
in events or objects

Claims: Value &
knowledge

Transformations

Records

Events
objects

When slightly modified in description, it can be used for teaching purposes too.

32. **Equilibration** (equillibrium)

It is a central concept in Piagetian view. It is a functional pocess different from structure. It is a regulatory factory, operating intenally in the biological organization. It is manifested in all life. It not only unifies evolution and development but also, at any moment, balances continuously the various operations of the system when faced with a new situation. It is in the nature of equillibrium to attain its balance and that too at a higher level. It thus provides a constat frame of reference to understand both the static and dynamic situations. It is the place of specific junction between the possible and the real. Equillibrium and structure are the two complementary aspects of any organisation of thought. In a way, it is the organizing factor underlying all biological and intellectual development.

33. Error

These arise due to centration on a single item regardless of its relations with other items. These are the cases absolute as well as relative over estimations in perception. Measurement can help since it verifies the learning situation. Then errors arise out of illusions. Error also appears when right rule or principle is applied wrongly, say in mathematics. It is then a case of xecutive error. It is a case of arbitrary error when either any answer is given or the rule is applied thoughtlessly in solving questions.

34. Error (Elementary)

These arise in perception due to over-estimation.

35. Experience

It is the sum total of one's interaction with the objects and persons in the environment.

36. Formal operations

These appear during the fourth stage of intellectual development as propounded by Piaget. Here reality is subjected to possibility. It is because of formal operations that children are in a position to react to absent situations, that is, situations which are no longer physically present before their very eyes.

37. Gestalt

It applies to the totality of the situation. It is rather imposed than applied and is not capable of being generalized It is lless mobile than scheme of thought.

38. Group and Groupaid

Let G be any non-empty set consisting of elements a, b, c.... By the binary operation O on G, we mean the function O : G X G G such that O (a,b) aob, where (G x G = (a,b) where a and b are the elements in G).

Groupaid: A non-empty set G with the binary operation, say, O is called groupaid.

Group: A groupaid G wih the binary operation O is called group if and only if it satisfies the following postulates:

(i) Associativity: For the elements a, b, c in G, a o (b o c) = (a o b) o c.

ii) Identity: If there exists an element, say, a in G such that eoa = aoe fr every element, then we say that e is the identity element or neutral element of G.

iii) Inverse: If for every element a in G there exists an element a^1 such that a^1 o a = a o a^1= r. Then we say that a^1 is the inverse lof a. Group G with the binar operation O is called commutative if and only if for every a, b in G, aob = boa.

39. Hypothetic - deductive thinking.

Here, thinking is tested in a very broad frame-work. Propositions are tested not only for their theoretical relevance but also the kind deductions which can be drawn and tested experimentally. It is here that reality is superseded by possibility. Theoretical research, say, in physics is a case in point.

40. Identity

It is a state of being a thing or operation itself.

41. Image

It is the intenal representation of an external object. It is one of the products of symbolic functions.

42. Imitation

It is an act by which the model is reproduced. It is the figurative correspondence of motor-activity to an external event. It has the following stages; sensory motor, deferred imitation (gesture) and internalized imitation (image).

43. Infancy

A term having a Latin origin 'infantia'. It means inability to talk. So it covers a period of two years from birth.

44. Innate

It is something not acquired but is present since birth. Innate behaviour patterns are called instincts. It is also necessary to distinguish between acquired learning and evolutionary learning which takes place with the passage of time.

45. Intelligence

This term is about 2000 years old. It was coined by Cicero. Piaget equated its usage with knowledge. It has two aspects, namely, biological and logical. It is an adaptation to new situation and that too without limits. Essentially speaking, it is an organisation whose function is to structure the universe. Lastly, it is also pictured as progressive reversibility of mobile structures constructed by it.

46. Interiorization

It is more or less synonymous with internalization. Here, lasting sort of dissociation takes place between the functional adaptation (general form of coordination) and the external action, say in imitation and language. In short, it leads from practical to operational intelligence, a pre-condition for the development of symbolic representation and objective knowledge.

47. Intuitive thought

It is a type of thinking in which a child seems to make judgements without any basis. This thinking is characterized by a fusion of ideas and statements.

48. Inversion

It is a type of reversibility in which one operation is negated by an opposite operation.

49. Knowledge (Figurative and operative)

Figurative knowledge focusses on the external aspect of an environment in a static manner. It is distinct from operative knowledge but cannot be conceived without it. Operative knowledge is the action-based aspect of intelligence.

50. Language

Action is the basis of language (Piaget). In a way, it is the "natural, spoken and heard symbol system" of communication prevalent in a society. Restrictedly speaking, its manifestation is acquired and thereby influences intelligence indirectly within the social educative influences of the society.

51. Learning

It is a change in behaviour. It is also defined as active search for the acquisition of knowledge. Here, there is a prior interior structure of equilibration which provides capacity to learn as well as the structuring of the learning process. In fact, it includes both.

52. Logic

It enables us to structure our spontaneous thought firmly. It is characterized by logical necessity/judgement and consistency etc. Sometime, it leads to absurd conclusions.

53. Logical Operations

(i) Conjunction: Conjunction of any two propositions (statements) A & B is denoted as A B which is true if both are true and false, if any one of A & B is false or both are false. It combines the statements having the meaning of the word 'AND'.

(ii) Disjunction: Disjunction of two propositions (statements) A & B is denoted by A V B which is true if any one of them is true and false if both A and B are false. V combines the proposition having the meaning of the word 'OR'.

(iii) Negation : Negation of a statement or proposition has opposite meaning. It is denoted by . If A is true when A is false and vice versa. Moreover (A) = A.

(iv) Implication: If from a given statement A or B proposition we are led to another statement or proposition, we say A implies B or A B.

(v) Equivalence: Given two propositions A and B, if A B and B A , we say A is equivalent to B. This equivalence is denoted by A B.

54. Logico-mathematical structure

It is a generalized system of operation/transformation which is characteristic of operational thinking.

55. Logical positivism

It is a philosophical view which holds that logic and abstract intelligence largely depend upon correct formalization and use of language. It is also seen as a modification empiricism. It says that language is the source of logical intelligence.

56. Maturation

It refers to biological changes with age within the context of behaviour development, for example, puberty. It is an inne process of growth which is little affected by training. Genes have much to do with it. In fact it results from the growth of the nervous system which enables the individual to handle learning, physical activity and even readiness to do a particular kind of act.

57. Memory

Restrictedly speaking, even active knowledge which may refer to a particulr past evocation of image and recognition does not imply memory. In a wider sense, memory is the availability of any knowledge which merely expresses the fact that the conservation of a scheme is identical with the functioning of the scheme.

58. **Motivation**

Within the context of developing knowledge it comes naturally to children. So, there is no independent role assigned to it in cognitive schematism.

59. **Monologue**

It is the tendency to carry on conversation with onself regardless of what others are saying. The social functions of words are conspicuous by their absence.

60. **Negation**

It is a type of reversibility in which one operation is cancelled out by the opposite operation.

61. **Metacognition**

t is cognition at a distance. It refers to the awareness of ognitive process while working a task. He also uses this wareness to control himself too in that situation.

62. **Number**

It is a fusion of seriation and classification. The conservation of number means that the number of objects remains the same in whichever over they are counted.

63. **Necessity**

It is the relation between the even, a statement and its basis. The question to be answered is: What must be ?

64. **Object** (Permanent)

It is polysensory complex which continues to exist outside the perceputal field. It is the invariant of group of displacements. The formation of the object is not a single shot affair. It is, on the other hand, gradually constructed as a result of accommodation and assimilation when the organism interacts with its surrounding environment. Object formation stands at the threshold of operational intelligence.

65. Operation

It is a mental act which involves classifying, seriating, combining, multiplying etc. It is applied to objects and even replaces objects by signs and movements. Some of its distinguishing properties are:

a) It is an action which is internalizable.
b) It is reversible and mobile.
c) It can negate its own activity.
d) It does not operate in isolation.
e) It is on the other hand, linked to other operations which constitute a structured whole.

66. Operativity

It is the action aspect of intelligence for all its four stages. It is the essential generalizable structuring aspect of intelligence within the overall context of knowing: constructing, transforming, incorporating etc.

67. Operator

It is an element which acts as a system to change its state.

68. Ordering

It is an operation of relating objects in a certain way, say, seriation on length, weight and size.

69. Organization

It is an inseparable part of adaptation. It is a totality, nay, a vaster totality in which its various elements are related not only to each other but also to the whole. It is the functioning of the organism which gives content to it. All biological phenomena find expression in it. It has its own intrinsic regulatory mechanisms.

70. **Perception** (Perceptual activity)

It is a knowing activity with focus on immediatelygiven sensory data. Perceptual activityis the co-ordination of successive centrations. So perception arises out of intellectual activity. In other words, to perceive is to construct intellectually.

71. **Play**

It comes naturally to children and develops in stages. It takes the form of make-believe fantasies in which assimilation predominates. Initially it is a case of functional (reproductive) assimilation. The terms is used in several contexts. Play assimilation, play of exercise, play egocentric, play with rules, and play of imagination. Egocentric play means to play for oneself. In symbolic play, the child uses other objects to represent those objects which are not present. It inheres its own belief which is subjective truth.

72. **Play** (Conpensatory)

Make-believe play in which children act out; say, fear, anger or aggression gradually with a view to coping with them.

73. **Preconcept**

It is a concept held by the child before it acquires a generalized character.

74. **Presence of symbol**

It is an event which is behaviourally characterized, "A sign is a significer", which indicates another even called significate. The organism may react jto the sign as a signal or a symbol.

75. **Pro**

It of equivalence between two or more

76. **Propositional combination or reasoning**

It relates to many possible ways of relating or combining the terms of a proposition or statement. It enables us to draw deductions which can be tested for relevance.

77. **Rationality**

It is concerned more with the methods of thinking rather than with its conclusions. It is not to be confused with exactness or accuracy. Similarly, irrationality is not error. It is a matter of degree too where one approach is more rational than the other. It is not true that the rational person is bereft of any emotions.

78. **Reciprocity**

It is a sort of reversibility in which the effect of a force or action is compensated for another force or action.

79. **Realism**

It is a sort of belief held by a child that whatever is real to him is real to others too: symbol, dream and feeling.

80. **Reinforcement**

The surrounding condition in which the individual reacts to a particular stimulus. Thus, the need of the individual is met. In the case of reinforcement (internal) the successful response appears due to the deductive activity of the mind.

81. **Representation**

It refers to something present which is not really present. So it is the capacity to evoke the absent object through sign, symbol and actions. It is detached from action.

82. **Reversibility**

It is the ability to carry out the same action in both directions. Then one can rach the starting point. Its two chief forms are negation (not male = female) and reciprocity (not better = worse). One is then able to reconstitute the phenomenon through construction as well as decomposition.

* Satisficing

It is a phenomenon encountered during problem-solv when the problem solver is satisfied on obtaining the appropriate answer. He does not go ahead in his thin for finding the best possible answer under given or where even the existing conditions can be chang In other words it is a choice ~~for~~ good enough for hi hence no further effort to improve upon it (A. Simon) the piagetian context the adolescent pupils fail to a the problem systematically and thereby exhaust all the and thereby very reluctant to go ahead. on the when one of the possibilities by sheer chance happ be the solution of the problem.

87. Seriation

It is the operation of ordering objects in the ascending or descending order. It can apply say, to length, weight.

88. Set

It is a kind of collection containing any kind of elements with or without a principle of selection. So elements of a set do not necessarily have any attributes in common.

89. Sign (Signifier, significant)

It is too general and arbitrary. To some extent , its appearance does depend on the presence of symbol.

90. Signal

It is more or less an elementary index or substitute stimulus. It is a seonsory impression which is associated with reaction as well as perception pictures of all schemes of thought with whom it gets assimilated. It tiggers the action of a scheme of assimilation. There is no difference between signal and signifier at the level of sensory motor habits.

91. Social transmission

Man does not live in vacuum. So it is a form of learning encompassing interpersonal relations, verbal instruction and social and cultural experiences.

92. Stage

It refers to development periods of intelligence, say, four within the Piagetian context. It has a lot of fascination in the Piagetian cont ext. It has a lot of tascination for working with the children, since each stage has its own specific features. It is their sequential nature rather than age specifies which is very important. Other workes like Freid and J.S. Bruner have also made use of this term in their writings.

93. Structure

In easier terms, it is also called organisation of experience. It is stored information about relationships held among elements of task, event, situation and cognitive symbols. Its various parts constitute a totality. It is more or less synonymous with organization system, form and co-ordination. At any moment, it is a momentary crystallization which is surpassed by minds functioning.

Its other features are:

1) It is invariably speaking a closed group.

2) It invariably leads to functioning, but not vice-versa.

3) It is stable at its centre but usually unstable at its limits.

4) It is at any time a particular form of equilibrium.

5) It is neither pre-determined nor a product of experience, physical and social. It is a form of equilibrium, a function of intellectual co-ordinations.

6) It is different to distinguish it from its contents because it is differentiated progressively. It plays the role of form and content simultaneously or otherwise.

7) It incorporates operations interiorization of activities. Once it happens , deduction becomes possible. The experience is thus rendered more or less useless.

8) It plays the role of regulators in respect of perceptual activities at the sensory motor stage. It as well plays the role of formation in the case of representative activities.

94. **Structuralism**
It is a school of thought usually contrasted with behaviourism. It studies problems such as structure of knowledge and memory.

95. **Structure d'ensemble**
It is necessary to imagine completeness as well as unity of thought in thinking at any stage of mental development. Groupings and INRC are the proposed structures at the concrete and formal stages of mental development. These structures are quite abstract and go a long way in uderstanding and capturing the essence of thinking.

96. **Symbol** (symbolic function)
It is an element which represents another thing or element. It has nothing to do with the thing represented. It is purely a matte of convention. Symbolic function, is therefore, the person's capacity to construct or produce a symbol for representing something which he knows to exist. It is individual and motivated. Here, both ideas and feelings are involved in toto. It is in fact an 'embryo of concept still charged with affectively'.

97. **Symbolism** (Collective)
Play in which each one plays his role within the total context of the play. In a way, each one is aware of the other's roles too.

98. **Symbolism** (Ludic)
Make belive games in which objects are used to represent other objects, for example, pencil as game.

99. **Syncretism**
It applies to the reasoning manifested at the pre-operational stage of mental development which explains cause and effect in terms of contiguvity. In other words, things and events

which happens together cause each other. The road, for example, causes the cycle to go.

It skips deduction. It has the tendency to connect anything to everythig else. It thus suffers from an 'excess' factor.

100. **System**

It is a set of elements with an organizing principle.

101. **Thinking** (thematic, explantory, productive, integrative, abstract stages in thinking)

In a general sense, it may refer to guessing, imagining, opining, remembering, reflecting and search for conclusions. In a restricted psychological sense, it may refer to percepts, image, vocal sound and ideas. In fact, it is quite a broad term. It then means an activity of the mind.

102. **Topology**

It is a branch of mathematics which studies jspatial relationships as well as forms without size or shapes. Examples are: open and closed figures as well as simple closed cover which divides as given plane into outside and inside. In other words, it (topological space) is a system of relationships expressed only in terms of proximity, separation, order, enclosure or continuity.

103. **Transductional**

It is a sort of (primitive) experience. It is a case of representation rather the concept. Specifically speaking, it is for all practical purposes, mentally evolved scheme of action. No deduction is involved. Thought is not conscious of its existence.

104. **Transformation**

It is of two types, namely: external and internal. The former refers to the constantly changing appearance of the world.

The latter refers to knowing whereby the confusing external changes are compensated through the construction of invariant. In othe words, operations are internal transformations which lead to the objective und erstanding of the world.

105. Transitivity

It is the ability to discover or to tanspose differences between items in a series. For example:

X Y Z

so X Z

or

Z X

106. Transposition

It refers to the transfer of the being of discrimination from task to task. In good form, the same structure is recognised when the same/similar situation is presented in a variety of ways.

107. Truth table

It is a table in which true and false values are shown in three or more columns of all possible combinations of attributes having two or more dimensions.

108. Verification

It is a process in which a person retests the idea of a statement.

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